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Workmen attempting to extinguish a burning oil tank, ordinarily a hopeless operation
FIRES IN THE OIL FIELDS—[See page 120]

A New Method of Studying Ideational and Allied Forms of Behavior in Man and Other Animals*

By Robert M. Yerkes,¹ Psychological Laboratory, Harvard University

DESPITE widespread interest in the evolution of reasoning, the comparative study of ideational behavior has been neglected. Only a few methods of research have been devised, and these have seen scant service.

Thorndike² is responsible for the problem or puzzle-box method (used by him in the study of cats, dogs and monkeys); Hamilton,³ for the method of quadruple choices (by which he has studied cats, dogs, horses, monkeys, rats, gophers and men); Hunter,⁴ for the method of delayed reaction (applied by him to rats, raccoons, dogs and children).

I have perfected and applied a new method—that of multiple choices—for the detection of reactive tendencies and the study of their rôle in the attempted solution of certain types of problem. The method involves the presentation to the subject of a problem or series of problems whose rapid and complete solution depends upon ideational processes.

The apparatus consists of twelve, or, in some forms, nine identical reaction mechanisms, of which any number may be used for a given experimental observation. In the type of apparatus originally used for human subjects, these mechanisms are simple keys; in that which has been used for lower animals, they are boxes arranged side by side, each with an entrance door at one end and an exit door at the other, which may be raised or lowered at need by the experimenter through the use of a system of weighted cords. Under the exit door of each box is a receptacle in which some form of reward for correct reaction may be concealed until the door of the appropriate box is raised by the experimenter.

It is the task of the subject to select from any group of these boxes whose entrance doors are raised that one in which the reward (food, for example) is to be presented. The experimenter in advance defines the correct box for any group of boxes which may be used as that which bears a certain definite spatial or numerical relation to the other members of its group. Definitions which have actually been employed (problems presented) are the following: (1) the first box at the left end of the group (as faced by the subject); (2) the second box from the right end of the group; (3) alternately, the box at the left end and the box at the right end of the group; (4) the middle box of the group.

The boxes are presented in varying groups in accordance with a prearranged plan. The subject is punished by confinement in the box selected every time it makes an incorrect choice and is then allowed to choose again, and so on until it finally selects that box which is by definition the correct one. It is then rewarded with food and permitted to pass through the box and return to the starting point, where it awaits opportunity to respond to a new group.

The experimenter keeps a precise record of the subject's choices and of various important aspects of behavior. These data include the nature of the choices from trial to trial, series to series, day to day; the appearance and fate of specific reactive tendencies or methods of attempting to solve a problem; and the final outcome, in success or failure, of prolonged effort.

The essential statistical features of the results obtained with certain types of subject may be summarized briefly thus:

*Two papers from *Proceedings of the National Academy of Sciences*.

¹Yerkes, Robert M., *The Study of Human Behavior*, Science, 89, 625-633 (1914).

Coburn, Charles A., and Yerkes, Robert M., *A Study of the Behavior of the Crow, Corvus Americanus* Aud., by the Multiple-choice Method, *J. Animal Behavior*, 5, 75-114 (1915).

Yerkes, Robert M., and Coburn, Charles A., *A Study of the Behavior of the Pig, Sus scrofa*, by the Multiple-choice Method, *J. Animal Behavior*, 5, 185-225 (1915).

Burt, Harold E., *A Study of the Behavior of the White Rat by the Multiple-choice Method*, *J. Animal Behavior*, 6, 222-246 (1916).

Yerkes, Robert M., *The Mental Life of Monkeys and Apes: a Study of Ideational Behavior*, *Behavior Monographs*, 3, serial number 12 (1916).

²Thorndike, E. L., *Animal Intelligence*, New York, 1911.

³Hamilton, G. V., *A Study of Trial and Error Reactions in Mammals*, *J. Animal Behavior*, 1, 33 (1911).

⁴Hunter, W. S., *The Delayed Reaction in Animals and Children*, *Behavior Monographs*, 2, serial number 6 (1913).

1.—Crows quickly solve problem 1 (first mechanism at one end of the group), with 50 to 100 trials.

Problem 2 (second from the end) they fail to solve in 500 trials. No consistent improvement appears, although there are four conspicuous reactive tendencies: (a) to go to the end box because of previous training in problem 1; (b) to go to the first box at the left and then to the one next in order, which in the particular experiment happened to be the correct one (this is the most nearly adequate tendency exhibited by the crow); (c) to re-enter whichever box happened to be chosen first and to choose next the second box from the left (correct); (d) to enter a box at or near the right end of a group, and on emerging, to turn to the right and enter the box directly in front, and so on until the correct box is located.

In the method of multiple choices, the crow gives no convincing evidence of ideational behavior. Its general intelligence is clearly indicated by alertness, keenness of perception, emotional responsiveness, and rapid adjustment to various essential features of the experimental situation. It appears to be temperamentally ill-suited to the kind of task presented by this method of studying reactive tendencies.

2.—White rats solve problem 1 in from 170 to 350 trials on the basis of certain acquired motor tendencies, one of which may be described thus: The rat follows the wall of the reaction compartment to the entrance to the box at the right end of the series of boxes. It then turns sharply to the left and passes along close to the boxes until the first open door is reached. This it enters. Kinaesthetic, tactual, and visible data constitute the basis for the motor habits by which rats solve this simple relational problem.

A single individual exhibited reactive tendencies less obviously describable in motor terms, but it is by no means certain that this indicates ideational ability sufficient for the solution of relational problems.

Problem 2 was not solved by rats within 800 trials, and there is no indication in the data that solution is possible to them.

Whereas the influence of training in problem 1 disappeared quickly when problem 2 was presented to the crow, it persisted in the case of the rat for about 100 trials. There are numerous other evidences, in the experimental data, of the higher intelligence of the crow. The rat is distinctly less versatile and markedly less responsive to slight changes in environment.

3.—Pigs solve problem 1 with 50 trials or less; problem 2 with 390 to 600 trials; problem 3 with 420 to 470 trials. Problem 4 is not solved in 800 trials.

These successes as well as the varied reactive tendencies manifested place the pig much higher in the scale of adaptive capacity than the rat or crow.

The data obtained with these three types of subject proves the method of multiple choices to be a feasible means of eliciting reactive tendencies which are characteristic of various points in ontogeny and phylogeny.

Results which have been obtained with monkeys, apes and men will be presented in separate communications.

The reactive tendencies of two monkeys and a young orang utan have been studied by means of the method of multiple choices described above.

Four multiple choice problems were presented: (1) the problem of choosing from among any group of mechanisms the one at the left; (2) the second from the right end; (3) alternately, the first at the left end and the first at the right end; (4) the middle mechanism.

Each of the three primates in question solved problem 1. One monkey (*P. rhesus*) required 70 trials; the other (*P. irus*), 132 trials. The ape succeeded only after 290 trials. The behavior of these three animals was most interesting and illuminating. *P. irus* was erratic, easily fatigued or discouraged, and apparently of low grade intelligence. *P. rhesus*, on the contrary, was alert, businesslike, intent on his task, and direct in his attack on experimental devices. The orang utan was childlike in his desire for assistance, as also in his resentment of annoyances or disappointments. He was given to settling down to a simple routine.

The accompanying Fig. 1 presents the curves of error for these animals as constructed from the data in connection with problem 1.

P. rhesus (Sobke) quickly and regularly eliminated mistakes and completely solved the problem. His disposition as well as his achievement is pictured by the curve of errors.

P. irus (Skirri) exhibited marked irregularities of performance, and the curve indicates his variable attention and effort as well as his slow progress toward success.

The orang utan (Julius) reacted uniquely, as his curve suggests. At the very outset he developed a definite habit of response which, as it happened, was inadequate for the solution of the problem but yielded constantly 60 per cent of correct first choice. The habit or reactive tendency was that of choosing each time the box nearest to the starting point.⁵ Julius continued to use this method without variation for eight successive days. Then a break occurred, but after a few days he settled back into the old rut. At the end of 236 trials, it was decided to try to destroy the ape's unprofitable habit. This attempt was made by using as correct boxes only those to the left of the middle box of the series. The nearest box, in such case, was never the correct box. Consequently, this modification of method greatly increased, as the curve of errors shows, the number of mistakes.

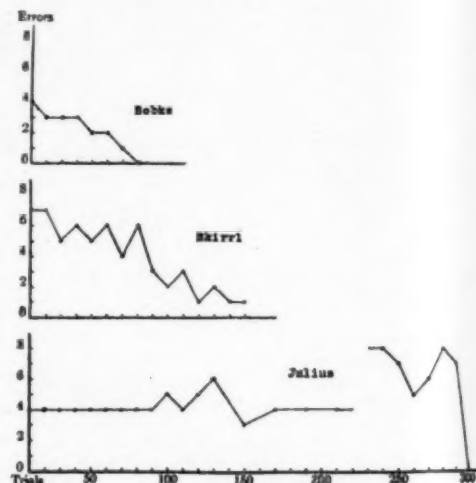


Fig. 1

For a few days after this change was made, no improvement in reaction appeared. On May 10, in a series of 10 trials, 7 were incorrect, but the following day and thereafter only correct choices appeared. Thus, suddenly and without warning, the ape solved his relational problem.

Is this the result of ideation? If not, what happened between the poor performance on May 10 and the perfect series on May 11? Because of varied results obtained in other experiments with this ape, I suspect that ideational processes developed.

The two monkeys succeeded in solving problem 2; the *P. irus* after 1,070 trials, and the *P. rhesus* after 400 trials. The orang utan failed utterly, although he was given 1,390 trials. Ultimately, he ceased to try to select the right box and followed the path of least resistance.

In addition to the method of multiple choices, the chiefly significant results of which cannot well be summarized, several supplementary methods of studying the adaptive behavior of monkeys and apes were employed. Chief among these are (1) a box stacking test; (2) a box and pole experiment; (3) a form of draw-in experiment.

The ape, although failing to stack boxes spontaneously in order to obtain a banana which was suspended from the roof of his cage, did so readily and skillfully when shown how to do it by the experimenter. His imitative activity was convincingly purposive. Previous to the opportunity to imitate the experimenter, he exhibited various methods of trying to get the banana. His attention was surprisingly constant, and his activity,

⁵In the apparatus used for these observations, the boxes were placed in a straight line instead of on the arc of a circle. Consequently, the distance from the starting point increased from the center of the series towards the end.

although varied, was for the most part definitely directed toward the food. In the controlling influence of the prospective reward and in the precision of execution of his various acts, Julius differed markedly from the monkeys.

Neither monkey made systematic and sustained attempts to obtain the banana by the use of boxes. Neither imitated the experimenter and neither attended to the prospective reward more than a few seconds at a time. These statements indicate a vast gulf, psychologically, between monkey and ape.

In the box and pole experiment, the banana was so placed in the middle of a long box that it could be obtained only by the use of a pole. The ape quickly, of his own initiative and with few useless motions, succeeded in obtaining the food. The monkeys never succeeded in obtaining it by any method and failed to use the pole at all as a tool.

Similarly, in an experiment which gave the animals opportunity to obtain food by drawing it into the cage with a stick, the ape quickly and repeatedly adapted means to ends by using the stick, whereas the monkeys never once attempted to use it.

The specimen of *P. trus* (Skirri) had a penchant for the manipulation of objects as tools. It is therefore surprising that he failed in the above experiment. When given a board, hammer and nails, he drove the nails into the board skilfully and persistently only to draw them out again and repeat the performance, for the activity was its own reward. In all probability, this use of hammer and nails was not imitative, since no other monkey or ape under observation showed any inclination to use them as did Skirri. Quite as assiduously and with evident satisfaction, he used lock and key, and saw, or any other object which happened to fall into his hands. In the use of a saw, he persistently refused or failed to imitate the experimenter, but finally hit upon a use for the instrument which clearly gave him great satisfaction. By holding it, teeth uppermost, with his feet and rubbing a nail or spike over the teeth rapidly, he succeeded in producing a noise which apparently delighted him. Skirri, although pronounced feeble-minded on the basis of various studies of problem-solving ability and reactive tendencies, proved himself to be a mechanical genius.

The general conclusions which may be deduced from

this limited experimental study of two monkeys and an orang utan are that the ape exhibits various forms of ideational behavior, whereas the reactive tendencies of monkeys are inferior in type and involve less adequate adaptation to factors remote in space or time. I suspect, from data now available, that both monkeys and apes experience ideas, and I believe that it will shortly be possible to offer convincing evidence of the functioning of representative processes in their normal behavior.

The original account of the results which have been summarized in this communication presents also a plan for a research station to be devoted to the study of the primates. It is pointed out that without scientific conscience we have permitted race after race of primitive man to disappear, unstudied by psychologist, sociologist, or anthropologist, or at best inadequately studied. The pertinent question of the comparative psychologist is, "Are we also to permit the gorilla, chimpanzee, orang utan, and gibbon to disappear before we make them yield their incalculably valuable contribution to human enlightenment, welfare, and the general progress of science?"

The Mystery of Metals*

THE biologist, the chemist, the surgeon has each no doubt his own decisive opinions as to the utterly fundamental basis of our modern civilization. The first may hold it to be man's superlative power of adapting himself to his environment. The second probably would insist that it is to be found in man's power of transforming Nature's raw materials into food and other products essential to our modern manner of life. The third perhaps may tell us that he finds it in man's power of being able to cure his own diseases. The engineer, if appealed to in the matter, can only answer that these opinions are wrong, and that in the strength with which Nature has endowed certain of her materials, and in man's ability to make use of such strength, is to be found the real master key to every aspect of civilized life, as we know it to-day. No engineer, it is believed, can reflect seriously on the matter without arriving at this conclusion. Is it not therefore truly amazing to find that, in spite of the vast edifice which has been raised on the possession of strength by a few natural materials, the engineer is utterly ignorant even to-day as to the cause of strength in the metals, woods, and stones which he uses? He knows with fair accuracy how much strength each possesses, and to a certain extent he knows how the amount of this strength is affected by variations in the treatment he may accord to the material exhibiting it. But as to why it should possess any strength at all, why the strength of one material should be different from that of another, why it should be different in two samples of the same material treated differently, he knows not at all. We do not pretend to be able to instruct him in the matter. For the present we only propose to discuss some of the difficulties which lie in the way of any one who attempts to investigate the cause of strength in metals and other materials employed by the engineer.

Let it be noted at once that recognized authorities on the strength of materials never discuss why materials possess strength. At most they will merely make some very brief and highly nebulous reference to intermolecular force. Yet, if we accept the molecular theory of matter, it is to the existence of intermolecular force that we must, in the end, attribute the strength of metals. What is the nature of such intermolecular forces in the case of solid bodies? That it is an attraction, and that it follows the inverse square law of gravitational attraction would appear, at first sight, too reasonable an assumption to require any justification. Justification, however, is to be found in the fact that the phenomena of surface tension and capillarity in liquids can be very satisfactorily explained on the assumption that the intermolecular force follows this self-same law. The inverse square law of attraction is, we know, true for planetary masses at planetary distances apart. It appears to be true for molecular masses at molecular distances apart in the case of liquids. Why should there be any doubt as to its truth in the case of the molecules of solids? There are two simple answers to this. First, the force between two bodies attracted in accordance with this law falls off rapidly as the distance between them is increased. Hence, the more a specimen of metal is strained under tension the less should become the force necessary to maintain the strain. The exact opposite is, of course, the fact. Secondly, assuming that this difficulty can be overcome, and that we can account satisfactorily for the

possession in a metal of tensile strength on the supposition that the intermolecular force is an attraction, how are we to explain, in keeping with this assumption, the possession in the same metal of compressive strength? As an indication of the state of opinion in this matter let us quote the words of one of our greatest authorities on the molecular structure of matter. In his book, "The Dynamical Theory of Gases," Mr. J. H. Jeans writes: "The fact that a solid body resists both compression and dilatation indicates that the force between molecules changes from one of repulsion at small distances to one of attraction at greater distances." There he allows the subject to rest, for his work is with gases and not with solids. But if we try to follow up this hint we find ourselves in difficulties at least as great as that which, to overcome, the suggestion of a change in the law is made. Thus we are forced to contemplate either a sudden change in the law or a gradual one in which the intermolecular force as the distance between the molecules decreases, changes from an attraction, vanishes altogether and becomes a repulsion. The supposition that the change is instantaneous is, to our minds, too "anti-physical," as Claude would say, to merit discussion. The alternative supposition would leave us to seek a state of affairs no evidence as to the existence of which has yet been noted, namely, that somewhere between being in a state of tension and a state of compression a specimen of metal should pass through a state in which the cohesion between some or all of its molecules entirely disappears. Is it conceivable that the molecules near the lower face of a loaded beam attract one another, that those near the upper face repel one another, and those on the neutral axis exert neither attraction nor repulsion on one another? Is this state of affairs compatible with the fact that the maximum shearing force is developed at the neutral axis, and has to be met by the action of those molecules which are out of action as regards resistance to tension and compression?

We see, then, that difficulties arise if we attempt to explain the strength of metals on the supposition that the inverse square law of attraction holds good between the molecules. We see, too, that, by supposing the intermolecular force to change from an attraction to a repulsion, according as the applied load changes from tension to compression, we merely raise fresh difficulties at least as great as those met with under the first supposition. Before adopting the second supposition—which, he it noted, does a certain amount of violence to other theories connected with the properties of matter—we ought to satisfy ourselves that the objections to the first are really such as to rule it out of consideration. Is it, as it is stated to be, truly incompatible with the possession in a metal of elastic strength both in tension and compression? We by no means feel convinced that it is. From a study of crystallography it appears certain that we are not justified in thinking of the molecules of a solid body as arranged simply at random, or even like a pile of round shot. We may reasonably suppose that they are grouped round the periphery or surface of some geometrical figure, such as a circle or a sphere. The elastic properties of a ring or sphere of attracting molecules are essentially different from those possessed or exhibited by the same molecules arranged like a pile of shot. The ring or sphere, for instance, can be deformed without separation of the contacting molecules, so that the force necessary to maintain the deformation does not essen-

tially fall off as the deformation is increased. It is not difficult to prove that a ring of six attracting molecules is in unstable equilibrium, and that any attempt to elongate or compress it will cause it to collapse of its own accord. Nevertheless, it is conceivable that, with higher numbers of molecules in the ring, a condition may be reached in which the ring, simply by the attraction between the molecules forming it, may be capable of resisting elastically both tension and compression. We make these remarks only to show that it is by no means easy to prove that the abandonment of gravitational attraction is necessary in order to explain the strength of metals. We do not for a moment suggest that this molecular ring theory is even a promising field for investigation. It should be noted that it regards the molecules as being at rest. Are we justified in neglecting the motion with which, according to the kinetic theory of heat, they are endowed? Remembering the well established effect of temperature upon the strength of metals we fear to answer that we are.

We are thus in this matter led from supposition to supposition until the accumulation of hypotheses becomes formidable. Let us therefore recall the words of one who himself devoted long years to the study of molecular physics. "If," said Clerk Maxwell, "we frame an hypothesis that the configuration, motion or action of a material system is of a certain definite kind, and if the results of this hypothesis agree with the phenomena investigated, then, unless we can prove that no other hypothesis would account for the phenomena, we must still admit the possibility of our hypothesis being a wrong one."

In recent discussions in the *American Machinist* the fact is brought out that situations will sometimes arise in which definitions of the terms *Gage*, *Die*, *Jig*, *Tool*, *Fixture*, etc., are called for. While anyone connected with shop production would undoubtedly know how to classify these terms, a difference of opinion might exist as to the proper definitions, as there are no standard definitions of these terms. The following definitions are suggested by one contributor:

Gage.—A mechanical device designed to detect variations of measurement in the location of surfaces, holes, projections or other dimensions. Sometimes of an adjustable construction, and when so made should be set to a standard of measurement or by the aid of a measuring instrument. If constructed in such a manner that it will measure the amount of variation detected without the aid of other instruments, it ceases to be a gage and becomes a measuring instrument, which brings it under classification of a tool.

Die.—A mechanical device consisting of two or more parts which when brought together in a power, hand or foot-operated press, or similar machine, will change or alter the form of hot or cold metals by cutting, forming, bending or causing the metal to flow, or perform any combination of these operations at one time.

Jig.—A mechanical device designed to hold parts, or one that can be attached to parts, which in either case has means whereby one or more tools that change or alter the form of the part can be suitably guided.

Fixture.—A mechanical device designed to hold parts while manufacturing or inspecting them, and that will hold the parts in the position desired, the guidance of the working tool, if necessary, being accomplished by other means.

*From *The Engineer*.



Fig. 16.—Sphere and horn gaps having a steep wave-front voltage applied
60-cycle spark-over voltage settings (kv.-max.)
Spheres 250 Horns 140

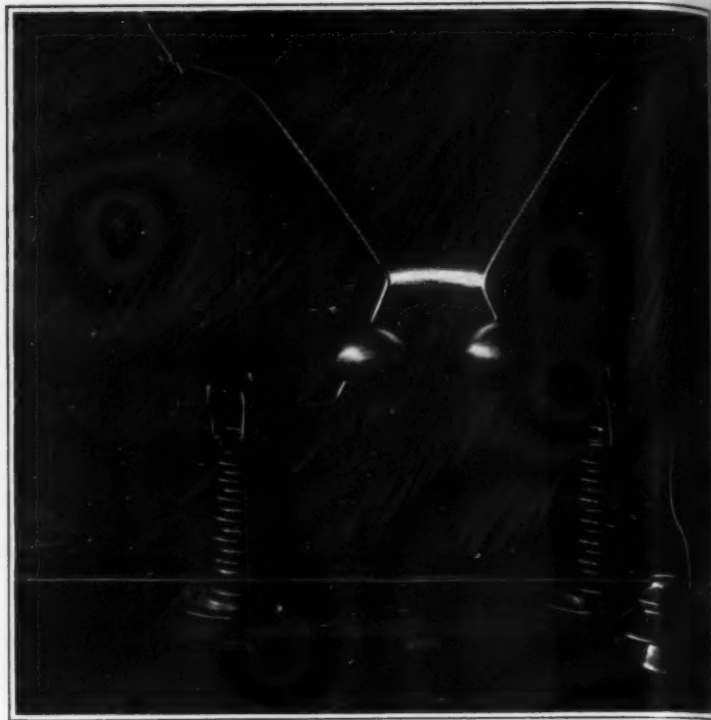


Fig. 17.—Sphere and horn gaps having a slanting wave-front voltage applied
60-cycle spark-over voltage settings (kv.-max.)
Spheres 250 Horns 140

Lightning*

Investigations of Time Interval Between Application of High Voltage and Failure of Insulation

By F. W. Peek, Jr.

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MANY peculiar and apparently inexplicable failures occur in insulation, line insulators, etc., due to lightning or surges. Lightning, for instance, may pass a needle gap set at a very low voltage, and strike across a higher voltage gap at the busbars or over a line insulator, etc. It requires small but finite time for a spark to form, depending upon the spacing, shape of the conductors, etc.; most of such phenomena are caused by voltages of steep wave front, or of extremely short duration, where the time to form a spark is limited. Steep wave front means that the surge, or lightning impulse voltage, is applied across the apparatus at a very rapid rate. Some of the phenomena about to be described were produced by voltages starting at zero and increasing at the rate of 1,000 kilovolts per microsecond.¹

A brief description of some of the effects produced by impulse voltages and the probable mechanism of breakdown for common conductors will first be given.

Spark-over, or failure of insulation, means a tearing apart or change in the atomic or molecular structure. In air, for example, it is supposed that there are always a certain comparatively small number of "particles of electricity" called ions. The negative ions or electrons have a mass of about 1/1800 of that of the hydrogen atom, and are attracted toward a positive, or repelled from a negative electrode or conductor. The velocity at which they travel increases with increasing voltage, or dielectric field intensity. When their velocity becomes great enough in their mean free path new ions are produced by collision with atoms or molecules. The neutral atoms become separated into positive and negative parts by the collision. The number of ions then rapidly increases until "ionic saturation" along some path, which is spark-over, finally results.² The field intensity, or the voltage gradient, at which this action starts, is always definite and, at ordinary atmospheric pressure, is 30 kv/cm.³ Any such process requires energy and, therefore, time, since the power is never infinite. Briefly, and regardless of any

theory of ionization, the process of tearing the air apart along some path or of building up a spark or corona always starts at a definite gradient or, for a given

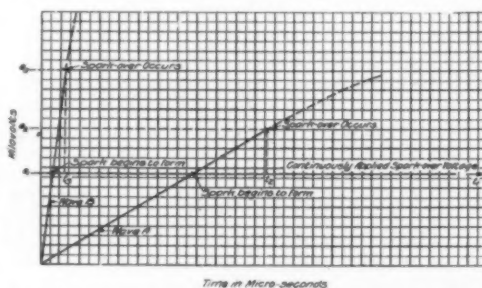


Fig. 1.—Diagrammatic illustration of why the "lightning" or impulse spark-over voltage is higher than the continuously applied

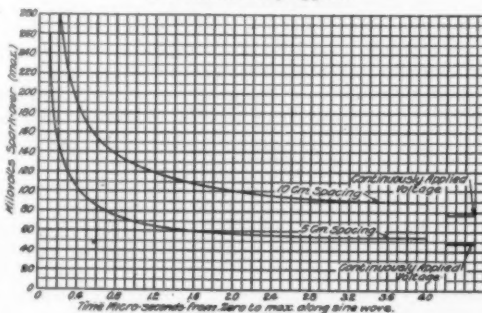


Fig. 2.—Time and voltage to spark over needle gaps (Sine wave impulse)

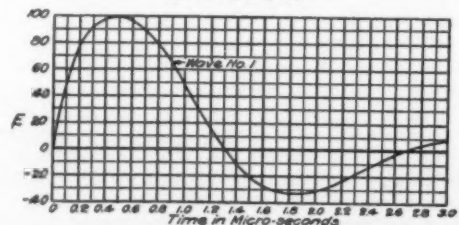


Fig. 3.—Approximate single half sine wave impulse (Only first half on the wave need be considered as the voltage is comparatively low after the first crest)

pair of electrodes when a given definite voltage is reached. After the process starts, a certain time must elapse before spark-over can take place and during this time the impulse voltage must rise to some higher value.

Referring to Fig. 1, the spark-over voltage of a given needle gap is e_0 , and always practically constant, if the time of application is not limited. Spark-over may take place after the continuously applied voltage, e_0 , has been on for some time t_0 . If a voltage increasing at a rapid rate as represented by A, in Fig. 1, is applied, spark-over will not take place when the continuously applied spark-over voltage, e_0 , is reached, as the time t_0 is required at this voltage. The spark will begin to form when the voltage reaches the value e_1 , however. The voltage will, therefore, rise above e_0 , and spark-over will take place after the time, t_1 , has elapsed and the voltage has risen to e_1 . When the voltage is applied at a more rapid rate along wave B, the spark, as before, will begin to form when voltage e_1 is reached. The voltage will continue to rise and reach the value e_2 during the time t_2 , before spark-over occurs. Thus, on account of the time lag, when voltage is applied at a very rapid rate, as by an impulse, spark-over does not occur when the continuously applied breakdown voltage is reached. The voltage "over shoots" this value during the time that rupture is taking place. The excess in voltage is greater, and the time lag less, the greater the rate of application. The time lag for any given gap or insulation has thus not a fixed value, but depends on the wave shape of the impulse or rate of application of the voltage. In making a study of such phenomena it is necessary to use certain definite wave shapes. Fig. 2 shows the impulse voltage-time characteristics for needle gaps. The impulses used in this test were single half-cycles of sine waves. Note that the impulse spark-over voltage is not greatly above the continuously applied or 60-cycle voltage when the time is over 5 microseconds; that is, when the time of application is comparatively long there may be a considerable variation of this time without an appreciable increase in the spark-over voltage. The continuously applied (60-cycle or d-c. where heating does not occur) spark-over voltage is the lowest voltage at which spark-over can take place.

Figs. 3 and 4 show actual wave shapes used in these tests*. Fig. 3 is equivalent to a single half-cycle of a

*For full description see "The Effect of Transient Voltage on Dielectric," by F. W. Peek, Jr., A.I.E.E., August, 1915.

*General Electric Review.

¹Microsecond = one millionth of a second. 1,000 kilovolts per microsecond = 1,000,000,000 kilovolts per second.

For complete description of tests, method of producing impulses, laws of impulse spark-over, etc., see "The Effect of Transient Voltages on Dielectrics," by F. W. Peek, Jr., A.I.E.E., August, 1915.

²Corona is spark from conductor to space.

³This short and general discussion of ionization by collision is not intended to be strictly technical.



Fig. 13



Fig. 14



Fig. 15

RELATIVE PROTECTIVE VALUE OF SPHERES AND POINTS

Line insulator shunted by a sphere-gap and a point-gap. The 60-cycle spark-over voltages are: insulator 120 kv.; spheres 137 kv.; points 77 kv. A 420 kv. "lightning" stroke applied to the line discharges across the sphere-gap. Although the sphere-gap has the highest 60-cycle spark-over voltage it protects the insulator and point-gap.

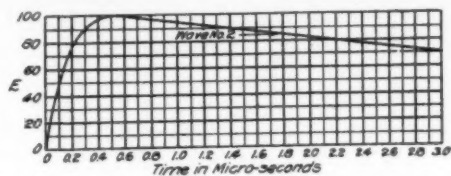


Fig. 4.—Impulse with steep front, but of comparatively long duration

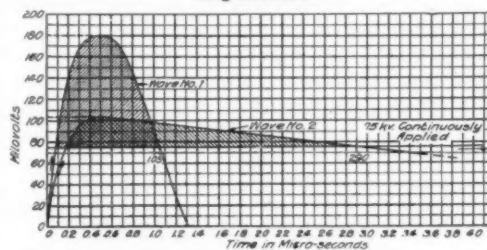


Fig. 5.—Continuously applied and impulse voltages to just cause spark-over of a 10 cm. gap between needles

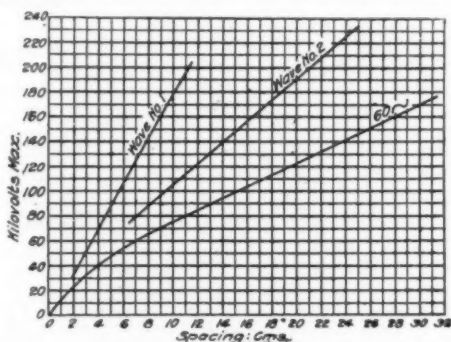


Fig. 6.—Needle gap spark-over curves for 60 cycles and for impulse waves Nos. 1 and 2, shown in Figs. 3 and 4

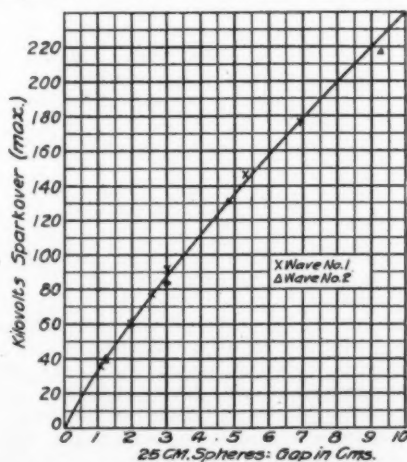


Fig. 7.—Sphere gap spark-over curves for 60 cycles and for impulse waves Nos. 1 and 2, shown in Figs. 3 and 4 (Drawn curve, 60 cycles—points, waves Nos. 1 and 2)

ine wave; Fig. 4 rises to a maximum at the same rate as Fig. 3 but has a flat top or is of much longer duration. Of the two waves shown in Figs. 3 and 4 the voltage required to spark-over a given gap should be higher for the one of shorter duration or for wave Fig. 3. This is shown from actual test in Fig. 5. For a 10-centimeter gap between needles wave No. 1 must have a maximum value of 180 kv. before spark-over can result; with wave No. 2 spark-over results at 104 kv. The spark-over at 60 cycles is 75 kv. The time that wave No. 1 is above the continuously applied breakdown voltage is 0.95 microseconds, wave No. 2, 2.70 microseconds. The impulse and continuously applied needle gap spark-over curves are given in Fig. 6. An examination of Fig. 6 shows that the impulse spark-over voltage of needles is always higher than the continuously applied spark-over voltage. For instance, with wave No. 1 the impulse spark-over voltage for a 10-centimeter gap is 180 kv., or 2.4 times the 60-cycle or continuously applied voltage. The ratio of the impulse spark-over voltage to the continuously applied voltage has been termed the impulse ratio.

The time to spark over a gap varies with the spacing and shape of the electrodes. For a given 60-cycle voltage setting the time required to form a spark is greatest for gaps between points and least for gaps between well rounded surfaces. For spheres, the time lag is so small that discharge takes place before the impulse voltage can rise appreciably above the continuously applied or 60-cycle spark-over voltage. This is shown in Fig. 7 where the drawn curve is the 60-cycle curve while the impulse spark-over voltages for waves No. 1 and No. 2 are represented by crosses and circles. The reason will appear later.

Place a sphere gap and a needle gap in multiple as shown in Fig. 8. Set each of these gaps to spark over at 75 kv., 60 cycles. The impulse spark-over with wave No. 1 is 180 kv. for the needles and 75 kv. for the spheres. If an impulse is applied it will always spark over the spheres. The sphere gap spacing may now be increased to 150 kv. 60 cycles spark-over, or double the 60-cycle spark-over voltage of the needle gap, as shown in Fig. 9. An impulse of wave No. 1 will spark over the spheres when the voltage reaches 150 kv., as 180 kv. is required to spark over the needles. If wave No. 2 is used the needles will spark over when the maximum of the wave is 104 kv. as given in Fig. 6, curve 2. Thus, when wave No. 1 is applied to this combination the sphere will always spark over. When wave No. 2 is applied the needles will spark over before the voltage reaches the sphere gap setting of 150 kv. A spark may thus be made to strike over either gap at will by a change in wave shape, the steep waves passing between the sphere and the slanting waves between the needles. This was actually done in the laboratory and is illustrated in Figs. 13 to 17. Spheres are always very much "faster" than needles.

The reason for the difference in time for spark-over of needles and spheres seems clear. The relative spacings for a needle gap and a sphere gap set at the same 60-cycle or continuously applied breakdown voltage is shown in Fig. 8. The needle spacing is much greater than the sphere spacing. Before the needle gap can spark-over, brushes or "spheres" of corona must first

form about the points and finally spark-over takes place along line 1-2, as illustrated in Fig. 10. The energy must be supplied through this air as it is ionized. The capacity between the points changes as the corona forms. This capacity must be gradually charged through the corona resistance before different sections are brought up to the breakdown voltage gradient. A vast amount of air must be torn apart or brought to ionic saturation. This may be readily observed by gradually applying voltage to the needles in the dark. The sphere spark-over requires breakdown of only the very small, short tube 1-2 shown in Fig. 10. The stress is practically uniform over this tube and breakdown takes place all along this tube at practically the same time. The relative settings of needles and spheres for a 140 kilovolt (max.) impulse spark-over voltage at various impulses are shown in Fig. 11. The sphere spark-over voltage is 140-kv. at 5.6 centimeters spacing and is the same for 60 cycles and for impulses. The 60-cycle spacing of the needles for 140-kv. (max.) is 25 centimeters; this spacing must be decreased to 15.5 centimeters (100-kv.—60-cycle) before a 100-kilocycle impulse will spark-over the needles; at 900 kilocycles the setting for 140-kv. spark-over is only 5.8 centimeters (5.4-kv.—60 cycles).

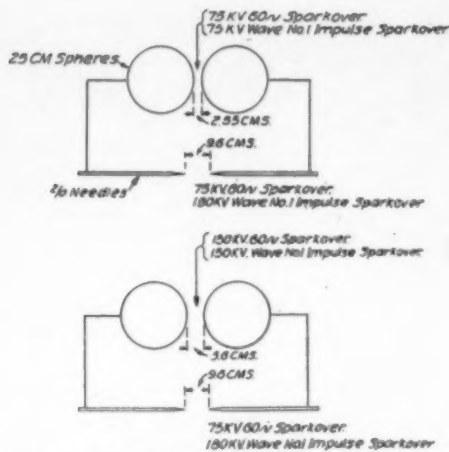
Assume now that a needle gap and a sphere gap are placed in multiple as in Figs. 8 and 9; that the 60-cycle setting of the needle gap is 100 kv. the sphere gap 200 kv. If a voltage is applied, increasing as shown in Fig. 11, spark-over will not take place at the needle gap when the voltage reaches 100 kv., but the spark will just begin to form; the voltage will continue to rise to 200 kv. and t microseconds later, the spheres will discharge after the voltage has increased to 200+kv. The needles cannot discharge unless the spheres are disconnected. If the spheres are disconnected discharge will then take place across the needles in the time, t , at 220 kv. If 60-cycle is applied and gradually increased spark-over will occur across the needles when 100 kv. is reached. If a needle gap and a sphere gap are set at the same continuously applied or 60-cycle voltage and placed in multiple an applied lightning impulse will always strike across the spheres.

In practice, lightning often discharges across a large space between busbars, line insulators, etc., in preference to point gaps which have a much lower 60-cycle setting. The explanation above makes the reason for this quite apparent. The lag at the point allows the impulse voltage to rise above their 60-cycle setting to a value sufficient to spark over the well rounded surface of the busbars where the lag is very small. The practical importance of utilizing these phenomena in design is readily seen. It is desirable so to design protective gaps that discharge takes place in minimum time, and so to design bushings, insulators, etc., that the time for the spark to form is maximum.

This is well illustrated in Figs. 13 to 17. In Fig. 13 an insulator is placed across the line and is "protected" by spheres and points, in multiple with the line, set at lower 60-cycle spark-over voltages are:

60-cycle Spark-over Voltages (kilovolts max.)
Fig. 13.

Insulator 120 Spheres 77 Points 77



Figs. 8 and 9.—Impulse spark-over of needles and spheres in multiple

The spheres and points are set at equal 60-cycle spark-over voltages. A steep impulse with a 420-kilovolt maximum is applied. The spheres spark over and protect the insulator and the points. The 60-cycle setting of the spheres is then increased in Fig. 14, while the needles are unchanged. The 60-cycle spark-over voltages are now:

Sixty-cycle Spark-over Voltages (kilovolts max.)
Fig. 14.

Insulator 120 Spheres 137 Points 77

The spheres still protect the insulator and points, although their 60-cycle spark-over voltage is higher than that of the insulator or points. In Fig. 15 the spheres are removed; the points are unchanged. The 60-cycle spark-over voltages are thus:

Sixty-cycle Spark-over Voltages (kilovolts max.)
Fig. 15.

Insulator 120 Points 77

The points fail to protect and the insulator sparks over. Corona may now be observed on the points. The impulse spark-over voltages of the insulator, spheres and points with 60-cycle settings as in Fig. 13 are:

Impulse Spark-over Voltages (kilovolts max.) Fig. 13.

Insulator 140 Spheres 77 Points 200

It is obvious, therefore, that the points can never protect the insulator against the steep impulse used in the above tests. In Figs. 16 and 17 the 60-cycle spark-over voltages are:

Sixty-cycle Spark-over Voltages (kilovolts max.)
Figs. 16 and 17.

Spheres 250 Horns 140

In Fig. 15 a steep impulse voltage sparks over the spheres although they are set at 1.8 times the 60-cycle spark-over voltage of the horns; in Fig. 16 a slanting wave sparks over the horns. A spark may thus be made to strike at will over either gap by changing the wave front of the applied voltage.

Lightning travels along a transmission line at the rate of 3×10^8 meters per second. Thus, a wave one kilometer in length passes a given point in 3.3×10^{-8} seconds or in 3.3 microseconds. By referring to Fig. 2

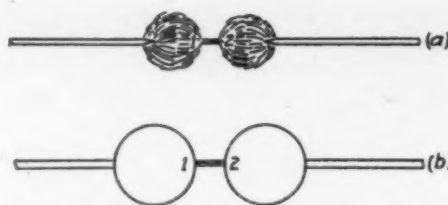


Fig. 10.—Diagram illustrating spark formation on spheres and on points

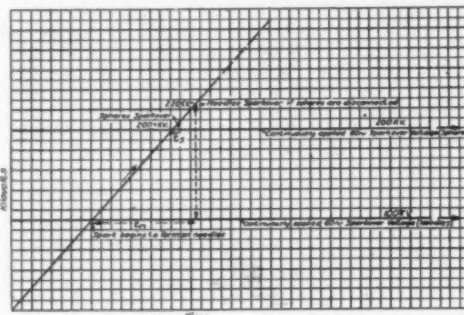


Fig. 12.—Diagram illustrating why an impulse may strike across a sphere gap even when the sphere gap is set at double 60-cycle voltage of a needle gap in multiple; how an impulse may be made to strike over either the sphere gap or needle gap at will by a change in the wave front of the applied voltage

it can be seen that a wave of the above length might easily pass by a needle gap before discharge could take place.

Line insulators and bushings may have equal 60-cycle spark-over voltages, but vastly different impulse of lightning spark-over voltages. As an example,

Insulator	60-Cycle Spark-over	Impulse Spark-over (Single Half-cycle 200 Kc. Wave)
No. 1	90	92
No. 2	90	130

Insulator No. 1 is smooth, insulator No. 2 has proper corrugations. The lag of No. 1 is very small, and No. 2 very large. Lightning impulses would readily pass by No. 2 and strike over No. 1. Insulator No. 1 would be difficult to protect from spark-over. Moisture from rain reduces the 60-cycle spark-over voltage of insulators from 20 to 50 per cent. The steep wave front impulse spark-over voltage is not greatly affected by rain. Line insulators may thus be weakened by rain or moisture for 60-cycle voltages, but retain their normal factor of safety for lightning voltages. Impulse sparks generally closely follow a surface.

The start of corona about a wire is spark from the conductor to space, over a small distance. The dielectric field over this small distance is fairly uniform for

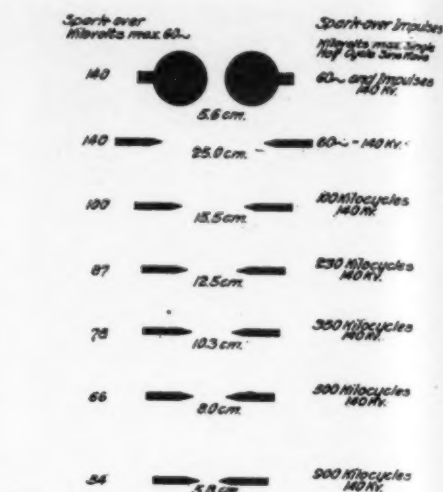


Fig. 11.—Settings of needle and 12.5 cm. sphere gap for equal impulse spark-over voltages of various wave fronts (Impulse voltage setting 140 kv. max. Waves single half sine 100 kilocycles and 900 kilocycles)

large wires. The lag is thus very small. Corona formation should be, for this reason, of some protective value on transmission lines. Considerable energy might be dissipated in this way by the kilometer wave mentioned. It is of interest to note that corona which is produced by voltages lasting only a few microseconds is readily seen.

Liquid insulations, compared to air, have a very great time lag. Transil oil is, therefore, an extremely good insulation for transient voltages.

Impulse voltages much higher than the low frequency operating voltages are generally required to rupture solid insulations. The effect of such over-voltages is cumulative. Each one, which is not in itself sufficient to cause complete breakdown, contributes to final rupture. Failures often occur, due to this cumulative effect, at apparently low voltages. Absorbed moisture greatly lowers the strength of insulation at 60-cycle voltages. Absorbed moisture has, as a rule, very little effect on the impulse strength. Different types of insulations of equal 60-cycle breakdown strength may have greatly different impulse strength. Dry or brittle insulations are generally badly shattered by over-voltages of steep wave front.

Many of the effects described above are those produced by impulses corresponding in duration to single half-cycle of sine waves of 20 to 1000 kilo-cycles. For surges of long duration the effects approach those produced by 60-cycle voltages. These effects must not be confused with those produced by continuously applied high frequency or undamped oscillations where burning occurs.

*For comparative tests, etc., see "Electrical Characteristics of Solid Insulations," by F. W. Peek, Jr., *General Electric Review*, November, 1915.

*"The Effect of Transient Voltages on Dielectrics," by F. W. Peek, Jr., *A.I.E.E.*, August, 1915.

A Milk Boiling Device

Among the various devices which are intended to prevent milk from boiling over, we noticed one which solves the problem in a very simple way, and the device is very easily made up, on the contrary to some rather complicated ones which are proposed for this purpose. It consists of a straight tube of say two or three inches diameter at the top and expanding somewhat toward the bottom, where it is provided with a flaring and cup-shaped end of rather large diameter, the whole being somewhat of trumpet shape. Out of the lower part are cut say four suitable openings, and we set the device upright in the vessel with the small end just out of the liquid. Should the milk tend to boil violently this action commences at the bottom, and the liquid is forced up the tube, then falls upon the surface again, so that the boiling action will continue in this way and the milk has no tendency to leave the vessel.

Securing Window Glass

GLASS panes can be held in place without the use of putty by the use of a flexible metal or rubber strip like a partly-open tube laid upon the pane and held down by a set of clamps spaced along the pane. First apply the pane of glass so as to fit it into the usual recess, then lay the prepared metal or spring strip along one side and screw on a plate at the corners of the

pane and say one at the middle, these being flat plates with a somewhat incurved edge where they take hold of the spring strip, and are screwed on the woodwork at the side of the pane with the curved ends projecting out and over the pane so as to enclose the strip. The latter are of course put on at all four sides of the pane. A double pane with air space between can be applied by using a deep recess and just laying a pane, then the strip, next a second pane and finally a strip that now comes flush with the woodwork and can be fastened down by the metal plate as before.

The Structure of Coal

SUITABLY prepared transparent sections of coals reveal under the microscope the fact that different parts of the coal substance are composed of different materials. The authors have undertaken the further separation and examination of the different parts of the coal substance, aiming at an ultimate correlation of definite morphological tissues or portions of tissues of the original plants with specific chemical substances now in or yielded by coal. When various coals are treated in a suitable manner, certain vegetable debris, such as wood, spores and cuticles, can be separated, and from some varieties of coal sufficient of each (botanically) distinct material can be obtained to enable a thorough chemical examination to be made. For example, the

authors have obtained a supply of pure cuticle, freed from all other debris of the coal substance, sufficient to allow of a study of its behavior under different modes of heat treatment, from which the products of its destructive distillation can be determined and its chemical constitution deduced.—M. C. Stopes and R. Y. Wheeler, *Brit. Assoc. From note in Journal of Society of Chemical Industry.*

Long Versus Short-Stroke Diesel Engines

It is concluded that for continuous operation, where reliability of service is specially important, the long-stroke engine is the more efficient, since it has the smallest fuel and lubricating oil costs, the lowest repair and maintenance costs, is more reliable in operation, has a longer life and is capable of taking a heavier overload for the same cylinder volume; for the same overload capacity a cylinder volume seven per cent smaller can be used with the long-stroke engine. Against these advantages has to be set the fact that the cost is higher and the weight greater than for the short-stroke engine. The latter type is hence to be preferred for small, lightly loaded installations, stand-by plants, and those installations where the capital cost has to be kept very low.—From a note in *Science Abstracts* on an article in *Zetts. Verneins Deutsch, Ing.*

The Pyrogenesis of Hydrocarbons*

A Review of a Discussion of Various Manufacturing Methods

THE term "cracking" has become so popular that one feels momentarily uncertain almost whether or not a communication on "The Pyrogenesis of Hydrocarbons" will deal with the same reactions and processes which are conveniently indicated by cracking. The papers discussed in the Institution of Petroleum Technologists recently certainly did deal with cracking, and when we go systematically into the literature with Mr. E. L. Lomax, we soon learn that cracking, though generally assumed to date from the carelessness of a stillman, who left a big fire under a still in 1861, may be said to be as old as gas lighting itself. For Murdoch proposed to make illuminating gas from oil in 1792, before coal gas lighting had really been adopted on any large scale, and Dalton cracked oil gas by electric sparks. Since then oil cracking has been studied and practiced for different purposes, chiefly for preparing illuminating oils, permanent gas, aromatic hydrocarbons, and fuels for internal combustion engines. Every cracking process yields mixtures of these various products in different proportions, and the aims have at different times been to favor the preferential production of the one or other product, in accordance with the particular demands of the time. It would be unprofitable to attempt to classify the literature on the subject with respect to the chief aims in view, and Mr. E. Lawson Lomax, M.Sc., did not attempt to do so in the very able and complete historical and bibliographical review of the pyrogenesis of hydrocarbons which he gave. This review formed Part I. of the paper submitted. In Part II. Messrs. A. E. Dunstan, D.Sc., and F. B. Thole, D.Sc., of the East Ham Technical College, discussed the general considerations of the pyrogenesis on broad lines. The communications were of considerable length, even without the full literature references which Mr. Lomax is going to add, and abstracting in the ordinary sense is out of the question.

Scientific investigation had begun long before Berthelot published his famous researches on the action of heat on various hydrocarbons in 1866. He started with acetylene, and concluded that at about 600 or 700 deg. Cent. the hydrocarbons reacted by direct affinity, and that they could all be synthesized from the lower members of a series. He also tried the opposite way, decomposing the higher hydrocarbons and mixtures of them by passing them through red-hot tubes, and subsequent research and practical work has proceeded on both these lines. The number of patents, researches, discoveries and rediscoveries is so large, the reactions are so complex and depend so much on circumstances, that we hesitate even to refer to the chief facts which Mr. Lomax accentuated in his rapid survey. The use of catalysts for the purpose of stimulating the reactions in particular directions and of lowering the temperature at which they take place, goes back about twenty years. The use of compounds like anhydrous aluminium chloride to bind certain products, in particular unsaturated hydrocarbons, subsequently to be released again, dates further back, but has quite recently come to the front again. Heating oil alone, in the liquid or in the vapor phase, and heating oil and water or steam, have all been proposed over and over again. Since 1906, Mr. Lomax stated, over sixty patents have been taken especially for making motor fuel from oil. The novelty of many inventions cannot but be questionable under these circumstances. Mr. Lomax also questioned the novelty of some of the worked processes about which he was able to give certain particulars. Thus he pointed out that the identical apparatus of Sir Boverton Redwood and Sir James Dewar of years ago "would do the same work in exactly the same way that the Burton process of the Standard Oil Company is doing at present." The process "apparently being worked" was to distill petroleum residues for the production of low-boiling hydrocarbons of the paraffin series at a temperature of 650 to 850 deg. Fahr., the whole plant being maintained at a pressure of 4 or 5 atmospheres by means of valves placed at the outlet of the condenser.

With regard to the Hall process,¹ probably the most successful being worked, Mr. Lomax remarked that the oil was passed up and down a continuous one-inch coil, 600 feet long, at temperatures and pressures to suit the desired product; the vapors were expanded at the exit into a wide tube, and this expansion down to atmo-

spheric pressure was accompanied by an appreciable rise of temperature, owing partly to the conversion of the kinetic energy of the gas (at high speed) and partly to the disruption of the molecules of the oil; most of the cracking and some deposition of graphitic carbon took place at that stage. The vapors then passed through a series of Raschig dephlegmators and, cooled to 100 deg. Cent., entered the compressors. When working for motor spirit (at 550 to 600 deg. Cent. at the exit tube) this compression was accompanied by a slight fall of temperature, probably because some of the lighter hydrocarbons polymerized. The optimum temperature and the rate of feed for any particular reaction had to be maintained, and were maintained, within 5 per cent.; that was most important. When working for aromatic hydrocarbons the temperature and pressure were 750 deg. Cent. and 105 to 110 pounds per square inch; the spirit that had been made for eleven months (during which tubes had been run for 250 hours without requiring cleaning) in a large plant (views shown) contained up to 18.5 per cent of benzene, 17.5 of toluene and 6 of xylene, with very little paraffin; the yields were good; 70 per cent of the oil could be obtained as motor spirit.

The Rittman plant of the United States Bureau of Mines and the Aetna Company, which we described recently,² was criticised by Mr. Lomax. They had installed six furnaces, each of two rows of five cracking tubes, 11½ feet high and 8 inches diameter, the furnace being heated by twenty-two gas burners. The tubes and their axial stirrer rods were unwieldy, the carbon deposits very troublesome; it was difficult to see how the stirrers could pass air-tight through the stuffing boxes at 700 deg. Cent. and 150 pounds per square inch; the oil vapor could not be properly and uniformly heated by passing through the tubes, and the claimed absolute control of temperature and pressure and the operating conditions looked very doubtful. The identification and estimation of the products obtained by the specific gravity tests seemed very unreliable, moreover, and the aromatic hydrocarbons prepared admittedly contained considerable quantities of non-aromatic bodies (not attacked by strong sulphuric acid); further, a Rittman plant to deal with 18,000 gallons of oil daily would require sixty tubes, costing £68,760, while a Hall plant of 10,000 gallons capacity would cost £12,000. Mr. Lomax further stated that Rittman's claim to have discovered, or practically established, that any type of oil would yield aromatic hydrocarbons might equally well be raised by Mr. Hall. The priority question does not interest us, and the cost estimates are too hazy; most of the other criticisms seem justified, and Rittman himself admitted that faults had been committed. Mr. W. J. A. Butterfield remarked subsequently that the design of the furnace should have been entrusted to gas engineers and not to the academic staff of the bureau; with tubes of eight inches diameter radiation from the hot walls would play as important a part as it did in partly filled gas retorts. One of the main technical problems is certainly to provide for efficient, uniform heating of the vapors drawn through the tubes.

In presenting the "general considerations," Dr. Dunstan said that there was no lack of bones to build up the skeleton of the pyrogenesis, but the reactions were very complex. Giving the thermo-chemical data for a large number of reactions, he pointed out that the reactions proceeding by absorption of hydrogen were in the main exothermic, that is to say, the products formed contained less intrinsic energy than their generators and were more stable, while a genuine cracking (splitting up) process was mostly endothermic, relatively unstable products (the unsaturated olefines) being formed which had a proportionately larger heat of combustion. The temperature coefficient of most of the reactions was surprisingly constant, but in changes of temperature, etc., the general law of Le Chatelier had to be borne in mind: When one or more of the factors determining an equilibrium were altered, the equilibrium was displaced in such a way as to neutralize the effect of the change. Hence, for instance, heat was liberated when carbon and hydrogen united to methane; when heat was admitted to this system the equilibrium was displaced in the direction that heat was absorbed and methane dissociated again. As regards reaction velocity, Dr. Dunstan quoted various examples: when 98 per cent of methane was decomposed at 675 deg. Cent. in six hours, e.g., the same decomposition would only take

five minutes at 800 deg. Cent. and a fraction of a minute at 1,000 degrees. The temperature at which cracking began depended upon the complexity of the molecule, the complex unsaturated compounds decomposing first; up to 500 or 600 deg. Cent. the resulting product would chiefly consist of olefines and paraffins; at 700 degrees of olefines, diolefines and aromatic bodies, with little paraffins; at 1,000 degrees mainly of permanent gases (methane and hydrogen) and a tar rich in aromatic hydrocarbons. These temperatures presumed atmospheric pressure. Increase of pressure in general raised the synthesis or combination, diminished pressure favored dissociation. With respect to catalysis the iron tubes of the apparatus were often more effective probably than the nickel or other catalytic material put into them; the catalytic action was probably a surface effect, not a specific effect of the substance, and depended little on the nature of the metal or oxide used. In the catalytic effect of aluminium chloride the hydrolytic formation of hydrochloric acid was probably a factor.

Coming to the mechanism of the pyrogenesis, Dr. Dunstan took an intermediate standpoint between Berthelot, who accentuated polymerization or condensation of simple molecules (especially of acetylene) to complex molecules, and Bone and Coward, who suggested a breaking up of the molecules into nascent radicals which reunited sometimes to cyclic compounds. Total disruption might take place at high temperatures of 1,000 deg. Cent., but for temperatures of about 500 degrees he preferred the less drastic views of Thorpe and Young and Haber. This exposition would lead us too far into strictly chemical problems, however. Dr. Dunstan concluded by showing a few experiments. Strong sulphuric acid binds the unsaturated hydrocarbons; when the acid was too strong, or the temperature too high, the reaction was so energetic that a tar was formed and an explosion might take place. By suitably grading the sulphuric acid treatment, however, Dr. Dunstan mentioned, Dr. Thole had succeeded in freeing the products entirely of the undesirable diolefines, which otherwise slowly separated out of the spirit as gums of an offensive smell and caused a great deal of trouble.

This was one of the chief points to which the discussion referred. Dr. W. B. Blackler mentioned that cracked motor spirit admitted of being mixed with half its volume of alcohol, the mixture boiling below 100 deg. Cent., although the constituents might run up to 250 degrees, but the formation of the gums was very troublesome. He had, however, he added later, found a remedy for raw spirit which contained about 9 per cent of diolefines; the treatment prevented the reoccurrence of the gums after months. Dr. Moliro Perkin, to whom Mr. Lomax had referred, said that he had, in conjunction with Mr. Fenchelle, heated the oil at so high a pressure (90 atmospheres) that it could not boil, and they had not been troubled with carbon deposits except when working with certain oils. But they had been disturbed by the gummy deposits. Treatment with 5 per cent of sulphuric acid had removed the trouble for a time; but when the spirit was kept for months, the gums were apt to reappear and to stop up the valves. Gasoline from the oilfields did not cause this nuisance, which no doubt could be overcome. Mr. E. W. Lucas, speaking as an engineer, thought that the rate of cooling the gas after cracking might be concerned in the gum trouble; different products might be formed, and no gums arise if the cooling were slow. He also said that he had found that an alloy of iron and manganese, prepared so as to resemble a sponge, made a very good catalyst. The catalytic efficiency of this alloy, which really behaved like a sponge, rose in a few weeks to a constant value, and then dropped off after months; the catalyst could then be regenerated by being heated, and the hydrocarbons it gave off in this distillation process depended upon the treatment the oil had undergone. We have already referred to Mr. Butterfield. He confirmed the concluding statement made by Dr. Dunstan, that the nature of the material to be cracked seemed to have little influence on the final products; he had recognized that twenty years ago. The practical demonstration of the fact seems, however, to have been left to the Bureau of Mines and to Mr. Hall. There is one more point from Dr. Dunstan's paper to be touched upon. Lunge, an authority on coal tar, had rather scoffed at the attempts at making benzene from petroleum; that had been in peace time, and might become true again in peace time.

*Engineering.

¹See Engineering, vol. xcix, page 250.

²See Engineering, page 155 ante. See also vol. xcvi, page 124.



Seven great steel tanks of 55,000 barrels capacity each burning at Shamrock, Oklahoma



A river of fire. Oil escaping from wells floats on nearby streams and often becomes ignited

Fires in the Oil Fields

Fighting Conflagration that Cost the Country Millions

By O. R. Geyer

"FIREMAN, save my oil well—here's \$5,000 for your troubles."

Thus is the brave fireman of the oil fields rewarded for his endeavors on behalf of capital. A fireman's job in the average city provides a vehicle for sufficient adventures to suit the average fireman's tastes in that respect, but for pure, unadulterated trouble let the ambitious fireman seek the oil field regions, where pay is given for results obtained and not for the hours on duty. While there isn't the inconvenience of having half a ton of bricks fall upon him, the oil field fireman has his troubles. For instance, if he isn't careful, his helmet may melt and run down his spinal column or a "gasser" may be unreliable enough to blow up the entire fire crew without warning.

Fires in the neighborhood of oil and gas fields are about as popular as furnace fires on the equator, largely because of the increased opportunities for destruction enjoyed by the red demon constantly making trouble for the oil man. Millions of dollars of oil and gas and property are lost annually in the country's oil fields in some of the most spectacular fires in history. An oil field fire is nothing if not spectacular, because it usually confines its destructive habits to a few hours of work. Running to fires in oil fields is not without its rewards for thrill lovers, especially since false alarms are rarely known in such districts.

Largely because of the constant fire hazard of the oil field business, the producers and operators are giving more time and attention to protecting their volatile interests. To this end fire fighting in the oil fields has been reduced to as near science as possible, and there is usually a splendid field of opportunity for the individual who becomes an expert in controlling and extinguishing oil and gas well fires which spring up in large numbers to plague the producers and operators. Cigarette and pipe smokers are about as popular as highwaymen in the average oil field community, and there are numerous oil field settlements literally saturated in oil in which the "No Smoking" sign is given respectful attention. Trees, ground, houses, derricks, pump houses, in fact everything is literally soaked in oil, ready to spring into a huge bonfire with little or no provocation.

In the Mid-Continent field, Oklahoma and Kansas, enough gas was wasted in fires within a few weeks to supply the needs of a city of half a million population for a year. Last year oil field workers and hangers on were afforded the spectacle of seven great "gassers" spouting forth flames at the same time, causing a property loss of hundreds of thousands of dollars within a period of ten days. Because of the enormous pressure which often forces the gas out of these wells at the rate of from 20,000,000 to 60,000,000 cubic feet of gas a day, the fire fighters have no easy task in extinguishing such fires. The city fireman seldom if ever has a more difficult task than that of capping or extinguishing a burning "gasser" with its pillar of fire reaching up into the air as high as 100 feet or more, depending upon the gas pressure. The roaring of these fires can be heard for twenty or thirty miles, and these pillars of fire light up the country for miles around like an enormous candle.

An oil well fire is equally as stubborn to fight, though the enormous pressure is missing, because gas is often the basis of the fire. The use of water in fighting such

fires is worse than useless, having about the same effect as the throwing of kindling into a furnace in an attempt to put out the fire. Live steam has been found the most effective way of smothering the flames, for that is the only way the oil field fire fighter can accomplish his purpose. When a fire breaks out it is necessary to obtain boilers and lay pipe lines to the scene of the fire, a much more difficult job than that of the ordinary fireman. Often the heat from these burning wells is so intense that the workers require the protection of huge asbestos lined shields and must work in relays.

A third form of fire fighting encountered by the oil field workers is the oil tank fire, which usually lacks the element of danger found in other oil field fires because



An oil fire in Oklahoma

it is allowed to burn itself out without molestation. There are thousands of the huge 55,000-barrel crude oil tanks scattered about the field and now and then a stroke of lightning will set one afire. There is little to be done in such an emergency other than to protect the neighboring tanks from the fire in so far as is possible. This end is accomplished by use of the large ponds built around each tank for just such emergencies. When a tank becomes afire a small cannon is brought up and the bottom of the tank punctured to permit the escape of the oil into the pond. Having a larger surface on which to burn the fire wears itself out more rapidly and with less danger. Heavy black smoke as dark as night hangs over the scene of such a fire for a day or more, obscuring the rays of the sun as completely as the mantle of night.

The frequency of oil field fires has given rise to a new profession, that of the professional fire extinguisher, an extremely profitable calling providing one becomes an expert at the business. There are numerous men in the oil field country who make a good living putting out such fires. The average run of fire fighters are taken from the ranks of the workers, all of whom are called upon to help in case of an emergency. Even these men are better paid than the average city fireman, receiving from \$4 to \$6 and \$8 a day as laborers in case the oil fields are at all prosperous, as they have been for the last two years. The boss fire fighter sometimes receives as

high as \$5,000 for a single job in addition to his expenses. Usually he undertakes to extinguish an oil and gas well fire for a lump sum of money and expenses. If the well is a particularly valuable one he is certain to receive a good year's salary for the one job. When there is no boss fire fighter, the company usually offers a reward to the man or men who can put out the fire.

The rank and file of these fire fighters usually live in settlements scattered among the derricks. No fire alarm system is required for them, as every oil field fire is attended by a banging and roaring which can be heard for miles, and everybody fights fire from the water boy to the superintendent or owner. In oil fields, which extend as far as the eye can see and are forests of derricks, even the smallest of fires has in it the possibilities of a conflagration which would sweep the entire district as clean as though the oil wells were swallowed up.

Being a successful boss fire fighter is almost as paying as being president, if one may judge from the example of Henry Bramer of Tulsa, Okla., known as the champion gas well fire extinguisher of the world. Bramer has extinguished more fires in "gassers" than any other individual, undertaking each job on a contract price, which usually averages \$5,000 in case of a big fire. During the first ten months of 1916 Bramer was called upon to put out five big gas well fires in addition to numerous other fires, and his year's earnings from this work totaled approximately \$25,000.

Sometimes Bramer's job occupies him for a few days, often a week and now and then a month. His hardest task was putting out the fire which destroyed natural gas at the rate of 40,000,000 cubic feet for thirty days, and he got \$5,000 for doing it above all expenses. He carries on his work before audiences of thousands of persons who are attracted to the scene by the noise and glare of the burning well which can be heard and seen for miles. His efforts to save a 25,000,000 cubic foot "gasser" were witnessed on one Sunday morning by 15,000 persons, 5,000 automobiles being gathered about the burning well at a safe distance. This huge candle lighted up the sky for twenty miles in all directions for five days before it could be snuffed out by steam.

Bramer's most difficult job was that of extinguishing the fire in the 40,000,000 cubic foot well referred to above, on which he worked for a month before his efforts were successful. Workmen in the neighborhood of the well noticed some Indians building a campfire in a ravine at quite a distance from the gasser which had not yet been placed under control, but paid no attention to it until some one noticed that the gas, being of unusually heavy quality, was hanging near the ground and spreading out over a wide area. With a yell he warned his companions of danger and they ran at about the same moment the gas and campfire blaze met. There was an explosion which would have torn them in pieces, and the huge gas well began to spout flames 20 feet in diameter and scores of feet into the air, shaking the ground as though an earthquake were busy.

Gas escaping from the the braden-head spread out over the ground to such an extent that it was impossible for workmen to get within fighting distance of the well. A cannon was brought up and the head of the casing shot off, allowing the gas to escape in one stream. Five large steam boilers were set up and pipe lines laid to

within as close a distance of the burning well as possible, but these streams of steam had little or no effect upon the blaze. Workmen, then under Bramer's direction, attempted to cap the fire with a huge iron-cone-shaped hood bearing a tall smokestack to allow the gas to escape. A large corrugated iron shield, lined with asbestos was necessary to permit the fire fighters to approach within proper distance. Poles were set up on either side of the fire and a heavy cable suspended between them to carry the heavy hood to a point directly over the well, but before the cap could be gotten in motion the flames had melted the cable.

A second attempt was more successful, but the smokestack was found to be too small to permit the escape of the gas. A new hood, eight feet in diameter, with a larger stack, was built and dropped over the well successfully. With the flames contained in the small area of the stack it was possible to smother them with the use of live steam. Workmen stood by and directed streams of water upon the hood to prevent its being melted while this work was being done. This was one of the most spectacular and difficult gas well fires to control ever known.

In this one district of Oklahoma, within a radius of a

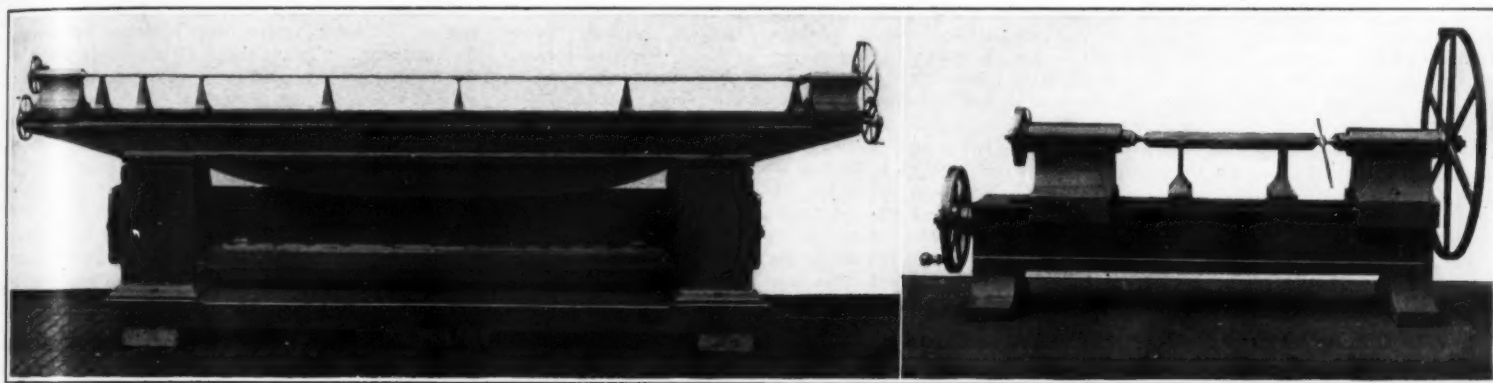
few miles, seven great gas wells were burning at one time, causing a daily loss of gas of 180,000,000 cubic feet. The gas by-product used in making high grade gasoline destroyed in this manner was worth \$40,000 a day, and as these fires raged for ten days, this loss alone was in excess of \$400,000. Nearly 2,000,000,000 cubic feet of gas escaped or was burned, which was equivalent to the loss of 90,000 tons of the highest grade coal.

The constant menace of fire has encouraged producers and owners of these great gas wells to take unusual precautions to prevent fires, and the government has been discouraging carelessness in this respect by fining operators \$300 a day when they permit this huge waste of gas without proper precautions to prevent fire or the huge loss caused by allowing the gas to escape unhindered. In sinking oil wells producers often encounter gas sands, and allow the gas to escape before continuing the deepening of the well to oil sands. The striking of a match in a ravine or low place near the scene of such operations would be the signal of an explosion of atmosphere of frightful proportions were it confined within a small area.

Oil well fires are extremely difficult things to control because of the stubbornness with which the crude oil

burns once it has been set afire. One of the most disastrous oil field fires in the history of the country swept a relatively small portion of the famous Cushing field in Oklahoma early in 1916, causing \$2,000,000 property damage almost within the twinkling of an eye. More than one hundred derricks, scores of homes and pump houses and other property were destroyed, while 20 oil wells, some of them producing oil at the rate of \$1,000 a day, were set afire. The efforts of hundreds of workers were required to prevent this huge bonfire from spreading throughout the entire field with its thousands of wells. Fanned by a strong wind, huge pillars of smoke and fire rolled over the heavens, attracting thousands of persons to the scene to watch the efforts of the fighters to extinguish the burning wells. Their curiosity was well repaid, for spectacular features abounded throughout the entire process of controlling and eliminating the fire.

It goes without saying that the average oil field fire fighter earns his pay, even if he is called upon to perform this service no more than once or twice a year. He is well content to pursue his duties of teaming or derrick building without being called upon for fire service, even the rewards may be great.



Machine developed in England for making accurate shop measurements

Shop Measuring Machines

By Frank C. Perkins

THE accompanying illustrations show two new Whitworth shop measuring machines developed at Manchester, England. The larger machine takes up to fifteen feet in length, the machine being in every respect on the same principle as the smaller machine shown.

The function of the machine is the comparative measurement from existing standards; thus given a six inch standard, another can be made any small amount under or over six inches. The measuring screw is in the fast headstock, with the large dividing wheel, one division of the latter representing 0.0001 inch end movement of spindle. It is pointed out that the movable tail spindle is arranged to be adjusted to suit the length being operated on, the divisions on the bed are to roughly set the tailstock in the most convenient position without having to try in the standard, and the divisions on the small wheel assist in adjusting the spindle, especially when it has been set up too tight and requires easing back. In that case the division can be noted and the wheel eased back and then brought up again within one or two divisions (as experience may dictate) of its previous position.

Let us assume a gage of 5.9342 inches length is required. It is necessary to move the tailstock inwards and clamp it at about the six inch mark, put in the six inch standard bar on the two supports and the gravity piece (noting all are clear), then set the large wheel to zero, the spindle projecting about 0.3 inch from the headstock, and then move the small wheel round slowly until the parts nip the gravity piece, but only just as much as will allow it to fall with its own weight. If the gravity piece is held too tightly, ease back and set up again as previously explained. It is then necessary to take out the standard, put in the new gage, give the large wheel one revolution equal 0.05 inch, and continue the movement to the marking 342, when, if the new gage is correct, the gravity piece should just fall as before.

It may be mentioned that if the new gage required is over six inches, as 6.0342 inches, on removing the standard it is required to make a complete revolution of the large wheel (spindle moving outwards) and bring it back to 342, when the machine is set for 6.0342 inches. In either case, of course, if the gage is large the gravity piece will be gripped before the reading is reached, when the difference will show how much is wanted off the gage. If at any time by over movement

of either spindle the object has been heavily gripped with more force than will nicely hold up the gravity piece, it is well to ease off the measuring wheel and move up again.

It is said that the limit of error of the length gages supplied is about 0.0001 inch, and the above supposes that the gage under test has more or less similar end surfaces ground square with the parts resting on supports. When a rough bar gage with rounded ends is required, the machine having been set as before, the gage can be passed between the faces by hand, the gravity piece resting on the support. Its error will not probably exceed 0.0002 inch if reasonable care is used. Short flat or round ended gages may be tried between the spindles by hand without the use of the gravity piece. The limit of error of the cylindrical gages is about 0.00005 inch, and for use in their manufacture the vernier fitted to measuring wheel is used, but only, of course, over short movements.

This smaller machine is arranged to measure by comparison with standard cylindrical length or other gages up to six inches diameter and twelve inches long and to the 10,000th part of an inch, or with vernier to the 100,000th part of an inch over small ranges. The machine consists of an accurately finished bed, with feet cast on and carrying a screw and hand wheel for quickly setting the moving head approximately to a scale of inches marked on the face; a moving head with screw and divided hand wheel for adjusting the hardened contact piece of spindle in touch with the standard; and a right hand fixed head with vernier, dividing wheel, screw and spindle with hardened contact piece for measuring.

Ancient Pit Dwellers in New Mexico

At a recent meeting of the Anthropological Society of Washington, Dr. Walter Hough, of the National Museum, read a paper on the above subject.

Dr. Hough said that remains of pit dwellings were indicated on the site of stone ruins explored in western Socorro County, N. M., several years ago and that a large cluster of such dwellings not connected with stone ruins was observed subsequently near Luna, in Socorro County. The site was productive of interesting results during an exploration for the Bureau of American Ethnology last summer. The field in which the remains occur had been smoothed over by natural agencies and the positions of the houses were shown only by the stronger growth of vegetation over circular areas, this defining the pits. Some of the pits were cleared, and

it was found that they were from 12 to 14 feet in diameter and 5½ feet deep. Remains of roof clay and charred posts and beams indicate that the roof was supported on posts placed around the periphery of the pit. It is thus probable that more than half of the house was underground, and perhaps the positions of the walls above ground were banked. The floor arrangement shows a fireplace near the center, a metate and grinding stones near the fire. In one of the pits a burnt clay wall fireplace was found. Adjoining the pits was a rectangular house also roofed with clay. Here were found numerous grinding stones, baking slabs, and remains of pottery, these being about a foot under the surface loam. This house was an open air cooking and mealing shed. Near the first pit excavated was a cemetery of infants; no remains of adults have yet been found on the site.

A dance amphitheater which was about 100 feet in diameter and ten feet deep lies on the east side of the site. It has been filled by natural agencies with about five feet of fire-blackened debris and in it large pine trees have matured. It is on the bank of the former and larger channel of a living stream which traverses the eastern edge of the site. The specimens found are crude metates, rubbing stones, hammer stones, baking slabs, etc.; pottery of Pueblo type, decorated and undecorated and of some crudity; a few bone awls and small obsidian arrowheads. No stone axes were found.

Dr. Hough presented the problem as he found it, and hesitated as yet to pronounce upon the affiliations of the people who constructed the pit houses.

Uses of Molybdenum

THE principal use of molybdenum is in the manufacture of alloy steels to which, particularly in conjunction with chromium, manganese, nickel, cobalt, tungsten and vanadium, it imparts many desirable properties. These steels are used for a large variety of purposes, such as for crank-shaft and propeller-shaft forgings, high-pressure boiler plate, guns of large bore, rifle barrels, armor plate, armor-piercing projectiles, permanent magnets, wire and for self-hardening and high-speed machine tools. Metallic molybdenum is used in various electrical contact making and breaking devices in X-ray tubes, and in voltage rectifiers, and in the form of wire for filament supports in incandescent electric lamps, and for winding electric resistance furnaces and in dentistry. Molybdenum is also employed in the manufacture of chemical reagents, dyes, glazes, disinfectants, etc.—*Bulletin No. 111, Bureau of Mines.*

Coconut Toddy in Ceylon*

Characteristics. Production and Uses of the Juice of the Coconut Palm

By K. C. Browning, M. A., and C. T. Symons, B. A.

(Government Analyst's Laboratory, Colombo)

AN attempt has been made in this paper to give some account of the constituents of toddy (palm juice) as drawn from the coconut palm (*Cocos nucifera*) in Ceylon. Since the product is a vegetable juice, and since the climate in this island is so variable, it is only to be expected that the analytical figures should show considerable variations.

As will be seen from the figures given in the third section, the industry which has grown up in connection with this product is a very considerable one, providing employment for comparatively large numbers of people and involving a fairly considerable capital in the island. With the exception of a paper by H. D. Gibbs,¹ and referring to the Philippine Islands alone, the present authors have been unable to find in recent scientific literature details of any exact analyses or examination of the product in question. Details are available for toddy (Tari) drawn from other palms. Such palm juice is largely used in India for making crude sugar; but the palms used in that country appear to be limited to the Date Palm (*Phoenix sylvestris*), the Palmyrah (*Borassus flabelliformis*), and the Kitul (*Caryota urens*).

METHOD OF DRAWING TODDY.

As mentioned above, this paper is limited to coconut toddy, and as the method of drawing toddy from this palm differs somewhat from that in use with other palms, a short description of the manner in which this is carried out in Ceylon is included in this section.

The part of the palm used for the purpose is the unopened flower spathe. This is prepared by the drawer ("tapper") for a considerable time (up to one month) before the juice actually begins to flow. The tapper, who is often a Cochin immigrant from Southern India, is scantily clad and carries fastened round his waist a belt which holds a broad tapping knife, a mallet of hard wood (vernac.: Keppetiya) or a piece of buffalo horn or bone weighted with lead, a small pot made of a half coconut shell containing a mixture of crushed leaves, etc., described below, an earthenware pot (chatty) or a gourd with cord attached, and a tin containing his tapping license. To climb the tree he may make use of bits of coconut husk which have been fastened previously to the tree trunk in the form of a primitive ladder. If these are not available he passes a small loop of fiber round both his ankles to hold his feet close together. With this simple apparatus he works his way up the tree, clasping the trunk between the soles of his feet (as a looper caterpillar clasps a small twig between its tail claspers), and holding the trunk with his arms. When he reaches the crown of the tree, he settles himself on one of the larger leaves and sets about his work.

If he is preparing a new spathe he merely bruises this with his mallet (making a noise like a woodpecker busily searching for a grub). The spathe is bound round with a few strands of fiber, etc., to prevent it from opening out prematurely. When the spathe is nearly ready to produce toddy, the tapper cuts off a small portion from the free end of the spathe, and places a chatty on the end, the pot remaining in position by its own weight. A spathe which is just coming into flower has its free end considerably higher than the other end. Hence any juice flowing from the cut end would naturally trickle down the stem and not into the pot. In order to obviate this difficulty the Sinhalese tappers when preparing a spathe, gradually bend down the free end, so that by the time it comes into use it is at such an angle that the juice will flow into the pot.

The Cochin tappers, who alone use bruised leaves, etc., to smear the cut end, are said to accomplish the same effect by the use of this greasy or mucilaginous mixture without bending the spathe. The application of the mixture appears to have also another purpose, as mentioned below. For the first few days of the tapping of a new spathe very little juice flows. When the juice starts to flow freely, the tapper visits the tree once or twice (in exceptional cases three times) a day, removes the collecting chatty, pours the contents into

the pot he himself carries, and lets this down by rope to the ground to be collected into a larger vessel by his assistant who remains on the ground. The tapper then takes out his knife and shaves a thin slice off the end of the spathe, taps the end with his mallet, and if he is a Cochin, smears the newly cut portion with the mixture of bruised leaves, etc., and replaces the collecting pot. This application is said to make the juice run more freely by preventing the rapid healing of the wound.

The leaves, etc., used in this mixture by the Cochins belong to several species. The mass usually includes cinnamon leaves (*Cinnamomum Zeylanicum*).

The substances used are lime (mineral), lime fruit (citrus), leaves of cinnamon (vernac.: "Kurundu"), wild cinnamon (*Litsea Zeylanica*, vernac.: "Dayul Kurundu"), shoe flower (*Hibiscus furcatus*, vernac.: Naabritta), other species of *Hibiscus*, *Aporosa* species, and *Eriodendron anfructuosum* (vernac.: Imbul).

In a *tope* (garden) the trees which are being tapped are usually "coupled" together by means of several strands of coire rope stretching from the top of one tree to the top of the next, so that the tapper may walk on this somewhat frail bridge from tree to tree, and thus save himself the trouble and time of an arduous climb and descent for each tree. In this way a tapper, using coupled trees, may be able to manage as many as a hundred trees per diem, whereas the same tapper could only work about thirty-five if they were not so coupled.

A Sinhalese tapper appears to be able to manage two or three times as many trees as a Cochin tapper. But the Cochin appears to be the more satisfactory of the two so far as yield per tree, etc., is concerned and is thus usually preferred by the tree owners.

Tappers are paid according to the amount of toddy collected. The collecting pots are usually left on the tree for twenty-four hours before the toddy is collected and taken away, even though the spathe has been prepared and cut twice in the day. The methods of tapping, etc., described above appear to have been in use from time immemorial. Robert Knox, who was a captive in the island for twenty years from 1660, gives in his book an account which agrees almost exactly with the above.

The yield of toddy per tree varies very considerably in the various districts in Ceylon, but cannot at present be correlated with any particular variation in elevation or humidity.

With one tapping per diem, the average daily yield per tree varies from about 600 cubic centimeters at Kurunegala on the border of the dry zone to about 1,200 cubic centimeters at Colombo, Mawanella and Anuradhapura, the last place being actually in the dry inland zone and the others on the moister west coast. With two tappings the average daily yield varies from 600 cubic centimeters at Matara in the south, to nearly 3,000 cubic centimeters at Mawanella, mentioned above. Three tappings per diem appear to give better results in some places, e.g., at Hatton (wet), where nearly 3,500 cubic centimeters are obtained per diem by this method.

The maxima and minima are also very variable. The greatest maximum recorded is 4,738 cubic centimeters, or more than a gallon, at Hatton, whereas the lowest maximum is just over 1,100 cubic centimeters at Hatnapura, also in the wet zone. The lowest minimum, exclusive of records taken when a new spathe was being started, was about 190 cubic centimeters.

It is generally agreed that the best yield is obtained when the weather is neither very wet nor very dry. Along the coast it is noticed that trees near the sea yield better than those further inland.

With reference to the age of the tree, the following is an extract from a report from the distillery district: "Vigorous trees of between twenty or thirty years of age are believed to yield best. . . . In my experience no rule can be laid down with regard to the age of the trees. Very old trees (more than eighty years old) in the Palyagalbadda District of the Kalutara Totamune which have been tapped year after year and which would be blown down if not supported by the couplings, yield best. They are very scraggy looking, but they are commonly known as 'toddy trunks.'"

It is quite usual to tap two spathes on a tree. The average time which is taken to use up a spathe, i.e., to pare it away, varies in different places from thirty to ninety days, much depending upon the care with which the tapper prepares it each day. If the spathe is one giving a good yield, a Cochin tapper will only shave off a very thin portion each time he taps. It is in his interest to get the maximum yield from each tree since he is paid by the number of gallons he draws each day. The total yield per spathe varies from 3½ to 17½ gallons, i.e., from about 15 to about 75 liters.

Trees which are being tapped do not give a good yield of nuts on the other spathes.

USES AND PROCESSES OF TREATMENT.

Coconut toddy, drawn as described in the previous section, is used for three main purposes, namely, for the production of crude sugar, as a beverage, and for the distillation of a potable spirit. It is also used to a small extent for the production of vinegar.

For use as a sugar basis, the toddy must be drawn unfermented. The inhibition of fermentation is usually attained by placing a small amount of slaked lime in the collecting pots each day, when they are put on the trees. This is the present official regulation with regard to the collection of sweet or unfermented toddy.

It was believed until quite recently that the bark and leaves of certain plants, if placed in the collecting pots, would prevent fermentation. These plants were *Vateria acuminata* (Sinhalese, "Hal"), *Cymbopogon pedunculata* (Sinhalese, "Ankenda"), and *Garcinia cambogia* (Sinhalese, "Goraka"). It was found by us on investigation that none of these was in any way effectual in preventing fermentation. Hal bark is, however, useful for clearing toddy which is to be made into jaggery (crude sugar), this action being presumably due to the presence of tannins in the bark. If an absolutely new unused pot is used for collecting the toddy, the liquid remains practically unfermented for a considerable time, possibly in part on account of salts dissolved out from the unused pot. Tappers say that a new pot must be used without cleaning for six days before the normal results are produced, i.e., before the toddy, when collected, is vigorously fermenting. In an old pot there is always a considerable accumulation of wild yeasts and bacteria on the inside. Hence fermentation is rapid, since the sugary liquid enters drop by drop into a strong culture of yeasts. On one occasion when we wished to collect normal toddy from a particular *tope* the owner was warned beforehand of our visit. In order presumably to please us he had everything cleaned up, even the toddy pots. Hence the toddy which we collected that morning was anything but normal, being practically unfermented.

If drawn in a glass pot, which is clean and practically sterile, toddy likewise remains unfermented.

Apart from the above-mentioned "liming" of the pots for sweet toddy, the process of tapping and collecting is carried out in the same way as for ordinary or fermented toddy, but in every case the yield of juice is very much smaller. This difference of yield is unmistakable. It is difficult to assign any particular reason for this.

The actual process of manufacture of the crude sugar (jaggery) from the sweet toddy is very primitive and is practically all carried out by small native proprietors.

The collected toddy, containing lime as stated above, is first strained to get rid of insects, etc., which swarm into the toddy pots; it is then boiled down in large earthenware pots over wood or coconut husk fires until it is of a syrupy consistency. When of the proper consistency, as ascertained by trial, it is poured into empty coconut shells and allowed to solidify. The resulting product varies considerably in color, from nearly white to dark brown. It is usually very deliquescent.

Approximately one and one half pounds of jaggery can be manufactured from one gallon of toddy. Locally this crude sugar is used as a substitute for imported sugar and for the preparation of sweetmeats. Its taste is quite characteristic. This industry in jaggery appears to have been of considerable importance in the past, since, according to Bertolacci, the value of jaggery exported from Ceylon in the year 1813 was 39,425 rix-dollars (£2,628). Since the introduction of cheap imported sugar and the increasing demand for copra

*Journal of the Society of Chemical Industry.

¹Philippine Journal of Science, 1911, 6, No. 3. See this Journal, 1911, 1133.

for the manufacture of coconut oil, the industry appears to have died down, as there is no record of any export of jaggery for the last few years. At the present time the chief source of jaggery for local consumption is Kitul or Palmyrah toddy.

As a beverage, toddy from the various kinds of palms before mentioned, i. e., coconut, kitul and palmyrah, is in very considerable demand in most parts of the island. The toddy as drawn from the trees (in unlined pots) is brought in the morning (and in some cases also in the evening) to the taverns where it is sold by retail. As will be seen from the next section, it varies very considerably in composition, but this is only natural since its fermentation, etc., is entrusted to any yeasts and bacteria which may make their way into the collecting pot on the tree. For the same reason this toddy must be treated as a perishable product (like milk) and cannot be stored under present conditions. To most Europeans its smell is repulsive; but when once this is overcome, fresh fermented toddy becomes quite acceptable as a refreshing drink. Though not clear, it is strongly sparkling, as it is still fermenting when consumed. In appearance it somewhat resembles very dilute milk. Its taste may be compared with cider in harshness, with at times a suggestion of flavor resembling champagne. It thus forms a good local substitute for beer. It should also be a very healthy drink, since it contains a large percentage of yeast; in fact, it may be said to be a suspension of yeast in a liquid containing a certain amount of alcohol, sugar and acid. However, it rapidly sours, and the morning's toddy is not pleasant to drink in the evening, except in cool weather or in the cooler parts of the island where the acid production is not so rapid. After twenty-four hours the liquid is too acid to drink.

Toddy is used as a food and drink combined by some of the fishermen along the coast, who start their day's work with only the fortification of a drink of toddy to sustain them. For the production of a potable spirit, arrack, a very considerable amount of coconut toddy is used in Ceylon. The process is almost entirely carried out in very primitive copper pot stills, heated by wood fires. Condensation is effected by means of a copper worm in a vat of water. This water is not circulated during distillation and no rectifiers are used. The resulting spirit is, as may be imagined, of a very inferior quality and is very seriously contaminated with copper, etc. The distilleries number rather over two hundred and fifty, and are practically all situated near the coast on the southwest of the island. In this distillery area most of the toddy is reserved for distillation.

The toddy is collected at the topes (gardens) in barrels, which are either carted to the distilleries or rolled along the roads thither. As most of the stills are very small, it might have been thought that sufficient toddy would be brought in each day to fill the still (100 to 200 gallons) and that it would be distilled as soon as possible, as fermentation is practically complete by the time the toddy reaches the distillery. This, however, is not the custom. It is usual to keep the toddy in open vats in the distillery for three or four days, by which time it has become very acid and much of the alcohol has become lost. As a result, the yield is poor and the product is bad. The condensing worm becomes coated with an acid greasy deposit which attacks the copper. The mere advice of a scientific visitor has, however, no effect in altering the custom of years, and the same wasteful process will possibly go on indefinitely.

The electrical conductivity was usually between 4,000 and 5,000 units. After heavy rain, the conductivity falls, owing to water getting into the pots, and has been found as low as 2,750 units.

The acidity (less CO_2) calculated as acetic acid was usually under one per cent. If the toddy is kept the acidity rises rapidly and with samples a month old acidities of over six per cent acetic acid have been found.

Sugar. Up to the present only sucrose (and, of course, dextrose and levulose) has been definitely found in the toddies examined. It is possible, however, that some contain a little raffinose.

As a rule, one particular source of toddy gives a fairly constant yield of sugar. For example, fifty-five samples taken from one district in August and September showed a variation in specific gravity of 1.060 to 1.068, the sucrose varying from 15 per cent to 18.4 per cent, the mean being 1.064, with an average yield of 16.9 per cent sugar. In conclusion the average percentage of sucrose in unfermented toddy is high and fairly constant, and an important industry could be developed by making crystalline sugar and fermenting the molasses left, by suitable ferments, for alcohol. The

present methods are crude in the extreme, and not only produce a very bad quality spirit, but are wasteful, losses of over fifty per cent of the available sugar being common.

A considerable number of samples of toddy have been examined in various parts of the island as sold over the counter in toddy taverns and also in the topes where tapping was taking place. The following figures give the results for fifty samples of coconut toddy.

Specific gravity, average 1.012, varying from 0.998 to 1.033. Acidity averages 0.51 per cent, varying from 0.32 per cent to 0.67 per cent reckoned as acetic acid.

Alcohol, by weight, averages 4.2 per cent, varying from 2.7 per cent to 5.8 per cent.

As is to be expected, there were very considerable variations in acidity and alcohol percentage, due to various soils, or the state of fermentation of the juice.

Gibbs (*loc. cit.*) gives the following figures for Philippine coconut toddy. The average daily yield of sap is 650 cubic centimeters and a good tree will give about 500 liters a year. The average composition of fresh sap is: Density 1.070, total solids 17.5 per cent, acidity trace, ash 0.40 per cent, sucrose 16.5 per cent, invert sugar, trace. Undetermined nitrogenous compound 0.60 per cent.

ORGANISMS PRESENT IN FERMENTED TODDY.

A number of samples of toddy were sent to Copenhagen for examination by one of the authors in the Alfred Jørgensen Laboratory. The specimens were sent on plugs of cotton wool in sterilized test tubes. On receipt the samples were placed in suitable media, and after a short delay growths appeared which were examined in detail. In most cases pure cultures were made, i. e., cultures grown each from a single cell.

Yeasts. The yeasts thus isolated consisted of the following types:

(a) *Saccharomyces cerevisia*, or some very nearly allied yeasts.

This resembled a typical culture yeast. Several strains of this yeast were isolated in pure culture and showed normal phenomena of sporulation and budding, with top fermentation.

(b) A wild *Saccharomyces*, resembling a wine yeast.

This was a typical "wild" yeast, somewhat resembling *S. ellipsoideus*, with rather large but otherwise typical highly refractile spores, in shape resembling oblate spheroids. Fermentation with this yeast was fairly rapid and very complete in a solution containing sixteen per cent of sucrose.

(c) *Schizo-saccharomyces*, or fission yeasts.

These were all typical fission forms, resembling *Schizo-saccharomyces mellacei*. Fermentation with these yeasts was rather slow in starting but gave a good yield.

(d) *Zygo-saccharomyces*, or fusion yeasts.

Somewhat resembling in phenomena *Z. Barkeri*, but of no interest from the fermentation point of view.

(e) A *Saccharomycode* form, resembling *S. Ludwigii*.

No species of film-forming yeast or mycoderma or torula was found.

Moulds. The species of these forms, which were present in a living state in the samples of toddy, belonged almost entirely to the class of moulds which most closely resemble yeasts, such as *Monilia* and *Oidium*. In the media available in the laboratory the specimens gave no signs of fructification, propagation showing itself only under the forms of budding and fission.

Bacteria. Many bacteria were found in the samples and any sample of toddy is always characterized by the presence of many long chains of these organisms.

It is not thought necessary to enter into any detail with regard to the organisms present in toddy, since, first, it is most probable that a sample of fresh toddy will be found to contain many more varieties than those which survived the journey to Europe, and second, it is hoped that it will be possible at some future date to make a complete examination, and publish the results in a separate paper.

Magic Plants of Ancient Americans

THE practice of magic was widely spread in both North and South America in pre-Columbian times, and in connection with it certain plants, principally those having narcotic properties, were used ceremonially, often as incense, or to produce hallucinations, to call up the spirits of the dead, and to expel evil spirits from the sick and insane. The priest of the Temple of the Sun at Sagomozo, in the Andes of South America, prophesied and revealed hidden treasures while in a state of frenzy caused by the seeds of a tree datura (*Brugmansia sanguinea*). This recalls similar practices of the priestesses of the oracle at Delphi. Another Peruvian plant with marvelous properties described by

early explorers was *Erythroxylon Coca*, from which the valuable alkaloid cocaine is now obtained. Bags of its leaves accompanied by little gourds containing lime were found by the author in many graves near the Peruvian coast, hanging about the necks of the mummified remains of the dead. On the opposite coast of South America, or rather in Paraguay, grew the highly esteemed *Ilex paraguariensis*, or *yerba mate*. Closely allied to it is the *Ilex vomitoria* of the southeastern United States, from which the Indians made the famous "black drink," used ceremonially as a magic phisic, which purged them from evil and which was used also in initiating their youths into manhood. Professional priests, or necromancers, were encountered by Columbus and his companions on the island of Hispaniola, who induced intoxication and called up their *zemi*, or gods, by means of a narcotic snuff, called *cohoba*, inhaled through the nostrils by means of a bifurcated tube. This snuff, hitherto believed to have been tobacco, has been identified recently by the author as the powdered seeds of a Mimosa-like tree, *Piptadenia peregrina*, still used in a similar way by various South American tribes of Indians, by some of whom an infusion of the seeds is also used to induce intoxication, administered as an enema by means of a pear-shaped syringe of caoutchouc. In Mexico, the early missionaries, who were called upon to stamp out the practice of witchcraft, found that the Aztecs paid divine honors to various plants, especially to *huauhtli* (a white-seeded *Amaranthus*); *ololiuhqui* (a *Datura*); *peyotl* (a spineless cactus, *Lophophora Williamsii*) also called *teonanacatl*, or "Sacred Mushroom;" and *picicell* (tobacco). Of *huauhtli* seeds, ground to a paste with the syrup of maguey, images were made and adored, and afterwards broken into fragments and served as a kind of communion. This seed was produced in such quantities that it was used in paying tribute to Montezuma, at the time of the Conquest. The *ololiuhqui* was regarded as divine, and it was considered a holy task to sweep the ground where it grew. Its spirit, addressed as the Green Woman (*Xoxouhqui Cihuatl*), was invoked to expel certain diseases and to overcome weaker and inferior spirits in possession of a sick person. It is interesting to note that the use of the *ololiuhqui*, or *tolatzin*, as it was also called (*Datura meteloides*), still prevails among the Zuni Indians of New Mexico, the Pai-Utes, and several tribes of southern California in certain religious and ceremonial practices, especially in initiating youths into the status of manhood. The *peyotl*, or *teonanacatl*, called by Bancroft the "flesh of the gods," was used by the Aztecs in nocturnal feasts, very much as it is still used by Indians of the Mexican Sierra Madre and by certain tribes of the United States, who believe the visions induced by it to be supernatural. In ancient times a supply of this little narcotic plant was obtained by runners especially consecrated for the purpose, and its gathering was attended by a most formal ceremony. At the present day it is sent from the locality where it grows, along the Rio Grande, by means of parcel post. Lastly, the ceremonial and religious use of *picicell*, or tobacco, goes back to remote antiquity. No other narcotic plant, perhaps, has become so widely spread or so generally used and beloved by its votaries. Though of subtropical origin its cultivation had extended before the Discovery as far north as the St. Lawrence River. Beautiful pipes of many forms, representing birds, mammals, human heads, etc., have been discovered in Indian mounds near Chillicothe, Ross County, O.; and more recently in Scioto County, farther to the south.

In addition to the above plants may be mentioned a certain small scarlet bean, the seed of *Sophora secundiflora*, endemic in northern Mexico and southern Texas. This also has narcotic properties, and was so much sought after by certain tribes of Indians that they have been known to exchange a pony for a string of the beans six feet in length. In one of the secret societies of the Iowa Indians this bean is used in the initiating ceremonial; the beans are carried as charms or amulets by the members of the society, just as in western Mexico fragments of the *peyotl*, and in southern California parts of the *Datura*, are carried by their votaries, who believe them to be efficacious against danger and to bring good luck in hunting and war. It is interesting to note a similar practice in the Old World of carrying the root of *Mandragora* (or a substitute for it) as an amulet; but most interesting of all is the similarity between the beliefs and practices of the inhabitants of the Old World and the New, in connection with narcotic and other plants held to possess magic properties.—From a paper read by W. E. Safford, of the Bureau of Plant Industry, U. S. Department of Agriculture, at a meeting of the Anthropological Society of Washington, D. C., and reported in the *Journal of the Washington Academy of Sciences*.

Illusions of the Upper Air*

A Review of Progress in Meteorological Theory in England Since 1866

By Sir Napier Shaw, F. R. S.

THE STUDY OF CYCLONES AND ANTICYCLONES.

IN 1866, a year after Admiral FitzRoy's death, the Royal Society undertook, by means of the new Meteorological Office, to establish seven other observatories in various parts of the country, equipped just like the Kew Observatory at Richmond, and to use the automatic records in explanation of the weather as set out in the daily maps. The explanation of the winds and the interest of the sailor were the justification of the public expenditure.

Meteorologists knew about cyclones from Piddington in 1848 and about anticyclones from Galton in 1863; from that time onwards until the end of the century the study of cyclones and anticyclones was the dominant idea of dynamical meteorology.

It was mainly conducted by observations at the earth's surface; and necessarily so. In 1852 Welsh, the superintendent of Kew Observatory, had made four sets of excellent observations of the upper air in balloons, and Glaisher had followed them up by a large number of ascents for the British Association, which reached their climax in the famous ascent with Coxwell in 1862. They added a good deal to our knowledge but very little to our ideas. They told us that the atmosphere showed continual decrease of temperature with height, and that surprised nobody; it was a natural incident in the gradual transition from the temperature of the surface of the earth to the absolute zero of space. "The nicely calculated less or more" was not of vital importance. Cyclones and anticyclones obviously belonged to the upper air, the regions where clouds are formed and dissipated, where rain and snow and hail are produced, but balloon ascents told us little about them beyond confirming the surmise that there are great ascending currents associated with certain forms of cloud.

The only real information to be got about the atmosphere in upper regions was that contained in observations of pressure at the surface, which is the cumulative result of the whole thickness of the atmosphere, and the amount of rain, hail or snow which falls from above. There were also observations of the forms of cloud and their motion, and, if we please, of their position. The rest is necessarily speculation, so that out of these observations meteorologists were obliged to imagine for themselves what cyclones and anticyclones are, how far up they extend, how they are produced and maintained, what kind of air they are made of, and so on.

OBSERVATIONS OF THE UPPER AIR.

Speculation can do a great deal with the atmosphere. It goes beyond the reach of our balloons, and tells us of the substitution of hydrogen and the rarer gases for oxygen and nitrogen in the region of the meteor and the solar electron. But from the year 1896 onwards there has been a systematic collection of facts about the upper air by using kites to carry instruments up to heights of three kilometers, or occasionally more; balloons-sondes which carry instruments up to heights of thirty-five kilometers (twenty miles or more); and pilot balloons which give the direction and velocity of the wind at various levels up to ten kilometers, sometimes more.

COMPARISON OF FACT WITH SPECULATION.

This investigation has given us a wealth of information about the upper air. The principal result is the division of the atmosphere into two layers: a lower layer about ten kilometers thick, the troposphere, the region of convection; and an upper layer, the stratosphere, in which there is no convection. We can use the information to test some of the generally accepted ideas about cyclones and anticyclones by comparing the results of speculation with the new facts. Many of the pictures which we imagined now appear to have been illusions. Those of us, for example, who thought that because the air was warmed from the bottom, the upper part would be free from sudden changes of temperature such as we get at the surface, were rapidly and rudely disappointed. Simplicity is not apparently the characteristic of the upper air.

THE CONVECTION THEORY OF CYCLONES AND ANTICYCLONES.

Before giving you other examples, let me quote the description by which Galton introduced the name "anticyclone," because the mental picture of the structure

of cyclones and anticyclones which has guided the thoughts of the majority of meteorologists has been formed by the gradual elaboration of the ideas contained in that description:

"Most meteorologists are agreed that a circumscribed area of barometric depression is usually a locus of light ascending currents, and therefore of an indraught of surface winds which create a retrograde whirl (in our hemisphere)."

"Conversely, we ought to admit that a similar area of barometric elevation is usually a locus of dense descending currents, and therefore of a dispersion of a cold, dry atmosphere, plunging from the higher regions upon the surface of the earth, which, flowing away radially on all sides, becomes at length imbued with a lateral motion due to the above mentioned cause, though acting in a different manner and in opposite directions."—*Proceedings Royal Society*, volume xli., 1862-1863, page 385.

Out of that there gradually grew the conception, on the one hand, of a central area of a cyclone on the map as a center of centripetal motion, a focus of attraction for the surrounding air, and of the general area of the cyclone as a region of ascending warm air producing rain or snow; round the central region the air moves inward with a counter-clockwise motion in spiral curves. On the other hand, the conception of the central area of an anticyclone is of a center of centrifugal motion, a region of repulsion; the general area of an anticyclone is a region of descending cold air moving with a clockwise motion spirally outwards. The fundamental dynamical idea is that of air driven like gas along a pipe from high pressure to low pressure, retarded by the friction of the surface, and diverted from its direct object by the rotation of the earth.

For future reference, let us separate the three elements of this picture and keep them distinct. First, the *circulation*, counter-clockwise in a cyclone, clockwise in an anticyclone. Second, the *convergence* across the circulation from high to low. Third, the *convection*, or vertical motion, which appears as ascending air in the cyclone and descending air in the anticyclone.

According to the conception which developed on the lines of Galton's description, and found ready acceptance, the circulation is incidental to the convergence; the convergence is universal, the convection general.

It is another example of the *facilis descensus Avernii*. The very simple piecing together of the three parts makes it almost obvious that the third element, the convection, is the effective cause of the whole dynamical process; it is natural to regard convection as the ascent of warm air in a relatively cold environment, causing low pressure on account of the relatively high temperature of the ascending air; and high pressure as the natural corollary of cold descending air. The convergence, or motion across the isobars, is the primary result of the distribution of pressure, and the circulation is merely the deviation from the straight path caused by the rotation of the earth. The theory is quite simple and quite self-contained, and it has this great advantage: that the cause which it assigns for the cyclone, namely, the convection of warmed air, has always been regarded as the cause of winds; it has been accepted as explaining land and sea breezes, the trade winds and the monsoons; and if it is also accepted as explaining the cyclone and anticyclone, which are the modern meteorological names for the diverse winds of the temperate latitudes, we can see in the idea a beautiful unity in meteorological theory. The origin of all the winds is thereby assigned directly to what we know must be their ultimate cause, namely, the warming of the lowest layers of the air by the warmed surface of sea or land. If we doubt its efficiency in one case, there seems no good reason for holding to it in the others.

It seems a pity that an illusion which apparently does such good service should be shattered; but it cannot face the facts of the upper air.

You will notice that the whole matter depends upon the idea of the low pressure in the warm ascending air of the cyclone as the driving force, whatever be the area covered by the circulation. The observations of the upper air have made us familiar with certain facts about the height of the atmosphere that make such an idea too improbable. The convective atmosphere is only about ten kilometers thick. The region in which

convection can operate is therefore a thin skin represented by a centimeter in the case of a map on the millionth scale, on which 1,000 miles is about six feet in length. A cyclone is often regarded as a towering structure which may produce curious effects by tilting its axis, but that is clearly illusory; the idea that descending air over northern France is operating in conjunction with rising air over Iceland to produce a flow of air along the line joining them is an unproductive way of representing the facts.

The idea of the ordinary cyclones and anticyclones in our latitudes as foci of centripetal and centrifugal motion is an illusion. In all ordinary cases of cyclone the convergence of the paths of air towards the center is itself an illusion, because the motion of the cyclone makes it miss its apparent aim, and we get in actual fact paradoxical cases of air which, always seeking a place of lower pressure, yet makes its way to a place of higher pressure, because the pressure has been raised over its path; and though it always seeks the center, in reality it goes further away from it. If it wanted to reach it, it was a mistake to aim at it; if it wanted to get near, it should have aimed to get away. There certainly is convergence and convection, but it is local and not general over the cyclone. The idea which is conveyed by convergence in spiral paths to the center of a moving cyclone is an illusion. It did not even require observation of the upper air to tell us that.

Take the time required for the operating forces to produce any such wind velocities as we find in actual experience. In one hour an ordinary pressure difference would produce a velocity of 1,000 meters per second if it were free to act. The time required to generate a velocity of, say, ten meters per second is infinitesimal compared with the time during which we see the forces in operation; these last for hours, or even days, while a minute would suffice for the production of all the velocities exhibited; the motion of the air which we register on anemometers is not accelerating motion but uniform motion, except for the effect of turbulence and local convection; so we must picture to ourselves the air of cyclones as being under the operation of balanced forces, not unbalanced forces. I wish to suggest that the idea of air being accelerated by the forces we see on the map is another illusion so far as the upper air is concerned.

The ostensible reason for supposing that the distribution of pressure created by convection is pushing air from high to low is due to the fact that the charted winds show the air at the surface crossing the isobars from high to low; the observations with kites and pilot balloons suggest that the effect is peculiar to the surface. If the driving force from high to low were the operative force which produces the wind of a cyclonic depression, we should expect to find its operation more strongly marked as we get higher up, because the friction of the surface would not interfere with it; but the fact is quite otherwise. The movement across isobars becomes less and less marked as we ascend. It is much less at Pendennis Castle than it is at Falmouth Observatory, a mile away. We cannot be sure that it exists at all at 1,500 feet, because we cannot draw the isobars at that level with the necessary accuracy; the consensus of our observations goes to show that there is no real evidence of convergence at that level. There the centrifugal force of the air traveling over the moving earth, combined with the centrifugal force due to the curvature of the air's path, is sufficient to balance the force due to pressure, and there is no component of motion towards the center.

What happens nearer the surface is that the friction of the surface converts part of the energy of the motion of the wind into eddy motion and the air does not move fast enough on the right path to keep up the balance. Consequently, it drifts inwards as a pendulum does when its motion is retarded, but the lower air cannot hold back the air far above it; the effect of viscosity in that direction was shown by Helmholtz to be negligible. The effect of the eddy motion is very limited in height.

*See "Life History of Surface Air Currents." By W. N. Shaw and R. G. K. Lempert. M. O. Publication No. 174.

*See the four reports on wind structure to the Advisory Committee for Aeronautics by W. N. Shaw and J. B. Dineen, also "Barometric Gradient and Wind Force," by Ernest Gold. M. O. Publication No. 190.

*From a discourse delivered at the Royal Institution. Reported in *Nature*.

OBSERVATIONS IN THE UPPER AIR IN RELATION TO THE CONVECTION THEORY.

But the greatest blow to the illusion that I have portrayed comes directly from the observations of the upper air; the convection theory requires that the air of the cyclone should be warmer than that of the anticyclone, but, as a matter of fact, the new observations show that the opposite is the case.

In a paper published by the Royal Society, Mr. W. H. Dines¹ gave the mean values of the observations of temperature in the upper air of this country arranged according to the pressure at the ground. From his results the following table has been compiled:

TABLE OF AVERAGE VALUES OF THE PRESSURE, TEMPERATURE AND DENSITY OF AIR IN HIGH AND LOW PRESSURE.

Height	High Pressure				Low Pressure			
	Pressure	Temp.	Density		Density	Temp.	Pressure	
	k.	mb.	A	g/m ³	g/m ³	A	mb.	
1000-ft.	10	273	226	421	382	225	247	
32.800	10	273	226	421	382	225	247	
29.528	9	317	233	474	444	226	258	
26.247	8	366	240	531	514	227	335	
22.966	7	422	247	595	583	232	388	
19.685	6	483	254	662	652	240	440	
16.406	5	552	261	736	724	248	516	
13.124	4	628	267	818	807	255	591	
9.843	3	713	272	911	893	263	675	
6.562	2	807	277	1012	992	269	767	
3.281	1	913	279	1137	1100	275	870	
0	0	1031	282	1270	1226	279	984	

The figures show that a pressure difference of 26 mb. exists at the level of ten kilometers where convection has ceased to exist. The difference is accentuated to the extent of 21 mb. as the surface is reached by the existence of the high pressure transmitted from above, in spite of the relative coldness of the air at the lower pressure. The diagram included in Mr. Dines' paper showed that there is a remarkable change at the top of the troposphere. Above the level for which values are given in the table, the high is colder than the low, reversing the state of things in the troposphere.

We cannot resist the conclusion that the pressure differences of cyclone and anticyclone are not local surface effects at all; we must seek their origin in the upper air where there is no convection. They are little affected by the lower stratum of nine kilometers, which, roughly, marks the range of the effect of heating at the surface.

The idea of warm air in the lower layers causing the low pressures which are recorded on our barometers is therefore an illusion.

Thus it will be seen that the observations of the upper air have proved that all the vital parts of the facile description which was the accepted theory of cyclones and anticyclones are quite illusory. What it took for guidance in forming a picture of the structure was the accidental character of motion near the ground. We now feel that the motion of air in the lowest kilometer had better be disregarded, or, better still, be handed over to students of turbulent motion, while we as meteorologists consider the normal state of the atmosphere as motion under balanced forces. Instead of a natural flow from high pressure to low pressure, we have a natural flow without any change of pressure; the motion of a heavenly body round its sun is taken as the type for the air instead of the motion of a falling stone.

While we are considering illusions, let me add another example depending upon what was at one time, and possibly is still, a commonplace of physical teaching in regard to the relation of barometric changes to weather.

It is this: moist air is lighter, bulk for bulk, than dry air, and consequently pressure is low where the air is moist. That is why a low barometer is indicative of rain; the moist air causes the low pressure. This is not true to fact. Mr. Dines has recently examined the correlation between the humidity of the troposphere and the pressure at the surface. The coefficient is quite insignificant; there is no relation between moist air and low pressure on the map.

But if the ideas which were common in meteorological practice fifty years ago are now to be regarded as illusory, let us consider what we have in their place. We go back to the three elements: the circulation, the convergence and the convection. As to the circulation, we now think of it as it is exhibited in the upper air, and instead of regarding it as an incidental disturbance of the motion from high to low, we regard it as the foundation of atmospheric structure; as the motion of air which is persistent because the pressure gradient

is balanced by the centrifugal action of the earth's rotation, which we may call the geostrophic component, and of the curvature of the path over the earth's surface, which we call the cyclostrophic component. If the balance between velocity and pressure is not perfect, the difference from perfection can be only infinitesimal, because in the free atmosphere the air must always begin to adjust itself to the strophic balance from the moment that any infinitesimal change becomes operative, and the power of adjustment arising from the extreme mobility of the air prevents any finite perturbation being set up, except temporarily in those regions where violent convection is operative. It is only through the mobile air that perturbation can be transmitted. We no longer picture to ourselves the air as being somehow held firm without moving until a pressure distribution is set up and then let go; the first symptom of pressure difference will be the occasion of motion, the distribution and velocity grow together; they adjust themselves automatically. The whole history of the general motion of the atmosphere is the story of the constant pursuit of the strophic balance, the adjustment of velocity to pressure, constantly disturbed by infinitesimal changes.

Near the surface things are much more complicated, because there is turbulence due to the interference of the surface and the obstacle which it offers to the steady progress of air. The air loses some of its motion, and is exposed to the pressure without the velocity that is required to balance it. It must, therefore, fall away towards the low pressure, taking out of the pressure the energy necessary to provide for the loss by friction. Thus the convergence which we have to account for is only that shown near the surface within half a kilometer. We need not trouble ourselves about a supposed convergence and convection over the whole area in the upper air. The second element of our specification disappears. After years of contemplation of the motion of the air from high to low as produced in a quiescent atmosphere by the operation of pressure difference and kept within bounds by friction, we now regard the motion from high to low as actually caused by the friction which retards the velocity required to maintain the strophic balance. To base the theory of motion of the upper air upon the idea of a given distribution of pressure setting a quiescent atmosphere in motion is as great an error as to begin the lunar theory by supposing the moon to start from rest under the force of the earth's attraction, and only to find out after it had started that the earth was moving.

As to convection, there is certainly convection wherever there is instability or the juxtaposition of air of different densities. It takes a great variety of forms; it is very common in cyclones, but it is not a necessary attribute of them. Possibly it is set up there more easily because the air travels so much faster in cyclonic areas than it does in anticyclones, and adjoining localities are fed from different sources of supply. Apart from a certain interference due to change of latitude, the convection is probably the one disturbing cause of the strophic balance of velocity and pressure. So we regard the troposphere as a layer of about nine kilometers thick, always striving to arrange its motion according to the pressure, and perpetually baffled in its endeavors by the ubiquity of convection. But since all the changes proceed by infinitesimal steps, there is never a time when we can identify a state of finite divergence from the balance between velocity and pressure. From this point of view the center of a cyclonic or anticyclonic system has no special dynamical importance. It becomes a notable feature on the map when for any reason the cyclostrophic component is the chief element in balancing the pressure. That is seldom the case in our maps, which more often consist of isobars of complicated shapes.

THE DOMINANCE OF THE STRATOSPHERE.

Further than this, Mr. Dines has thrown a new light upon the origin of differences of pressure at the surface by obtaining the correlation coefficient between corresponding deviations of pressure from the normal at the level of nine kilometers and at the ground, and has obtained results "ranging from 0.67 for the last available set of a hundred soundings on the Continent to 0.88 for soundings in England grouped for the winter season." Moreover, the standard deviations are of the same order of magnitude at both levels—that is to say, both levels are subject to similar changes. At the same time, the correlation coefficient between the pressure at the surface and the mean temperature of the nine-kilometer column is small; in other words, the temperature of the lower strata of the atmosphere has, on the whole, little to do with the general distribution

of surface pressure in this country. Its effects are local.

We must therefore regard the general flow of air, except in so far as it is disturbed by convection, as governed not by what happens at the surface, but by what is imposed upon it from the stratosphere above. It is from there that the general control of the distribution of our pressure comes. It is only modified by what happens below. The upper air, the stratosphere, is the operator, and the lower air the subject operated on. After fifty years of strenuous endeavor to regard the surface as the operator and the upper air as the subject, the exchange of rôle is very disturbing, but it has its compensations. There are many things which can easily be explained by operation from above, but only with the greatest difficulty by operation from below. Let us indulge in some speculations which follow from supposing that the stratosphere operates upon the troposphere. It makes the troposphere as tuneful as an organ under the alternating rarefaction and compression caused by the changes in the stratosphere. Every cloud is the subject of its action. One can imagine them being developed, showing first the region of greatest humidity, like the development of a photographic plate, which further develops into loss of stability, and so into cumulus cloud and a shower. And let us not forget that each several cloud means the disturbance of the normal circulation; the condensation will alter locally the horizontal distribution of temperature, and therefore that of pressure and wind. On the table are two autochrome photographs of the western sky at Ditcham Park, with a quarter of an hour's interval, on a September evening in 1911, with gradually reddening clouds that gradually vanished as they approached from the west. Nothing could be more attractive than to speculate upon such changes in relation to the changes of pressure in the stratosphere.

THE RÉGIME OF THE STRATOSPHERE.

But our new point of view only shows our problem removed one step further; we have now to begin again and imagine for ourselves what is the régime of pressure and winds in the stratosphere until the enterprise of meteorologists completes our knowledge of what it actually is. The problem is, at any rate, much simplified, because convection is avoided; we deal with an atmosphere which, being nearly isothermal, is inherently stable; density goes directly with pressure, layer lies on layer like a light liquid on a heavy one; temperatures are uniform, or very nearly so, in the vertical direction, and therefore isotherms are also isobars, and winds are proportional everywhere to pressure differences—that is, to temperature differences. Outside the equatorial region the rotation of the earth secures that air always moves along the lines of pressure, keeping high pressure or low temperature on the right. So the general idea is simple, but whether the streams of air are long, straight currents or central whirls we do not yet know.

NUMERICAL CALCULATIONS.

Speculations of a qualitative character are apt to lead the spectator into serious error; the real test of any physical theory is its quantitative application.

It will be of great advantage to the further development of our ideas if we can trust implicitly to the hypothesis of pressure balanced by motion (let us call it the principle of strophic balance) as the foundation of the structure of the atmosphere, and that hypothesis will be confirmed in the orthodox scientific manner if the quantitative conclusions to be drawn from it are verified by observation. I propose to ask your attention to some applications of that hypothesis which can be tested numerically.

From this point of view the theory of strophic balance has the great advantage of giving a definite relation between wind velocity, pressure and temperature, and therefore brings the relations between all these quantities within the region of arithmetical computation.

Let us consider some of these relations. We require a number of symbols for the meteorological quantities:

- p represents the atmospheric pressure.
- θ represents the atmospheric temperature.
- ρ represents the atmospheric density.
- l represents the horizontal distance.
- h represents the vertical height.

$s \left(= \frac{dp}{dl} \right)$ represents the horizontal pressure gradient

$q \left(= \frac{d\theta}{dl} \right)$ represents the horizontal temperature gradient

v represents the velocity of the wind.

$R = p/(\rho\theta)$ represents the constant of the gas equation.

Certain geodesic quantities also come in, viz.:

E , the radius of the earth.

¹See M. O. Publication No. 2106. Geophysical Memoirs No. 2.

g , the acceleration of gravity.

r , the angular radius of a small circle on the earth's surface which indicates the path of air in a cyclone.

λ , the latitude of the place of observation.

ω , the angular velocity of the earth's rotation.

We require also some convention as to the positive and negative of v .

v positive represents the winds when the pressure difference Δp represents higher pressure on the right of the path.

The fundamental relation between the velocity of the wind at any level and the pressure gradient there is:

$$s = \frac{dp}{dl} 2\omega r \sin \lambda = v \cot r \quad (F)$$

The two terms which make up the right-hand side of this equation are of different importance in different places and circumstances; for example, if the air is moving in a great circle r is 90 deg. and $\cot r$ is zero; the first term alone remains. On the other hand, at the equator the latitude $\lambda = 0$, $\sin \lambda$ is zero, and the second term alone remains. Away from the equatorial region the second term is relatively unimportant unless the velocity v is great. In temperate and polar latitudes the path of the air differs little from a great circle except in rare cases near the center of deep depressions; consequently the first term may be regarded as the dominant term in these regions.

We call the wind computed according to the first term the geostrophic wind, and regard it as generally representing the actual wind of temperate and polar regions.

We call the wind computed according to the second term the cyclostrophic wind, and regard it as generally representing the actual wind (in so far as there is any regular or persistent wind at all) in the equatorial regions. It represents the wind of tropical hurricanes, and winds of the same character may also occur locally in temperate regions as tornadoes and other revolving storms.

Thus we have the following auxiliary equations:

$$\text{Horizontal gradient of pressure} \dots \dots \dots s = \frac{dp}{dl}$$

$$\text{Horizontal gradient of temperature} \dots \dots \dots q = \frac{d\theta}{dl}$$

$$\text{Winds of temperate and polar regions—geostrophic winds} \dots \dots \dots s = 2\omega r \sin \lambda \quad 1$$

$$\text{Winds of equatorial regions—cyclostrophic winds} \dots \dots \dots s = \frac{v^2}{r} \cot r \quad 2$$

$$\text{The measurement of pressure} \dots \dots \dots \left(\frac{dp}{dh} = -g \right) \quad 3$$

$$\text{The gaseous laws (assumed for dry air)} \dots \dots \dots p = R\theta \quad 4$$

From these by simple manipulation I have deduced the following:

$$\text{For change of pressure gradient with height} \dots \dots \dots \frac{ds}{dh} = g \left(\frac{q}{\theta} - \frac{s}{p} \right) \quad A$$

$$\text{For change of wind velocity with height—geostrophic winds} \dots \dots \dots \frac{dv}{dh} = \frac{v}{\theta} \frac{d\theta}{dh} + \frac{g}{2\omega \sin \lambda} \frac{q}{\theta} \quad B$$

$$\text{cyclostrophic winds} \dots \dots \dots \left(\frac{dv}{dh} = \frac{v^2}{\theta dh} + \frac{gR}{\cot r} \cdot \frac{q}{\theta} \right) \quad C$$

DEDUCTIONS FROM THE THEORY OF EQUIVALENCE OF PRESSURE DISTRIBUTION AND WIND.

These equations serve to explain the following facts established by observation:

1.—Light winds in the central region of an anticyclone.

It follows from the fundamental Equation F when the negative sign is taken, as it must be for an anticyclone, that the values of v will be given by the roots of a quadratic equation, which will be impossible

if v is greater than $\frac{E \sin \lambda}{\cot r}$. This, for a circle of 70 miles diameter, only allows a velocity of about 4 meters per second.

This is confirmed in practice, and furnishes a crucial test of the two theories. If an anticyclone is a place where air descends and flows outward, its velocity should diminish as the air spreads outward; but the reverse is the case with an anticyclone.

2.—The small influence of the troposphere, and therefore the dominance of the stratosphere, in the distribution of surface pressure.

This follows directly when numerical values are inserted in Equation A. The right-hand side of the equation consists of two terms which are of opposite sign and, numerically, approximately equal in the middle regions of the troposphere. Their combined effect for the whole range is therefore relatively small, and the change of pressure produced in the troposphere is unimportant. The distribution of the stratosphere is dominant throughout the troposphere.

3.—The apparently capricious variations of wind and temperature with height disclosed in pilot balloon ascents and by balloons-sondes.

The results of the observations of balloons-sondes show local variations of temperature and those of the observations of pilot balloons show similar variations of the direction and velocity of wind. These variations can be connected numerically by Equation A in combination with Equation 1. A number of examples are given in a paper read before the Royal Meteorological Society. To quote one, the rapid transition from a southerly wind at 1,100 meters through a calm to a northerly wind at 1,500 meters on October 16, 1913, was shown to indicate a temperature gradient of 7 deg. per hundred kilometers towards the east, a condition that was in satisfactory accord with the meteorological circumstances of the time.

The same combination of equations enables us to specify the conditions under which "Egnell's law," that wind velocity at different heights is inversely proportional to the density at those heights, may be expected to be verified and the conditions prescribed are essentially reasonable.

4.—The rapid falling off of wind in the stratosphere noted in observations with pilot balloons.

This is illustrated by Fig. 1, a diagram compiled

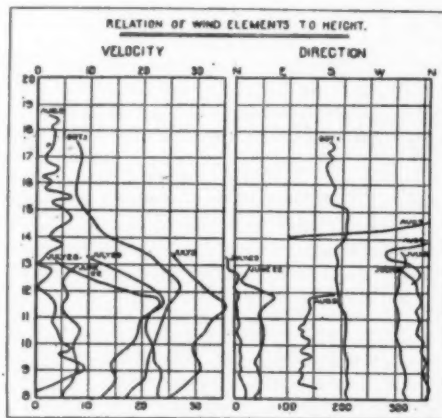


Fig. 1.—Diagram showing the falling off of wind velocity in the stratosphere (about 11 kilometers). The scale on the left gives the heights in kilometers, those at head and foot the velocity in metres per second, and the direction in degrees from north respectively.

from the figures of high soundings reproduced in Captain Cave's "Structure of the Atmosphere in Clear Weather." The result follows directly from the application of Equation B to the special conditions of the stratosphere. The computations for the four occasions in which there was a wind of considerable magnitude at the base of the stratosphere give the following results:

Date 1908.	Rate of Change of Velocity in the Stratosphere. M/S per Kilo.	Horizontal Temperature Gradient.	
		Computed Degrees per 100 Kilos.	Observed Degrees per 100 Kilos.
October 1.....	7	2.1	—
July 31.....	5	1.5	—
July 29.....	11	3.3	3.3
July 28.....	13	4.0	—
July 27.....	—	—	2.5

The calculation has been arranged to give the computed horizontal temperature gradient, because the values of that quantity can be taken directly from the

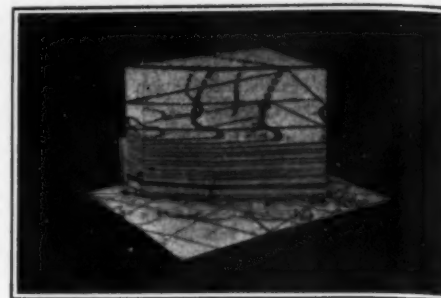


Fig. 2.—Glass model showing the distribution of temperature in the atmosphere on July 27, 1908. Isotherms are drawn for every 5° A., and the thickness of each line represents half a degree except in the case of the isotherm of 273°, which is covered by a band 5° in width. The height of the model represents 24 kilometers. The tilting upward of the isothermal lines shows the commencement of the stratosphere at about 11 kilometers.

models of temperature distribution constructed in the Meteorological Office for July 27 and 29, Figs. 2 and 3. The order of magnitude which is indicated is quite reasonable, and for the one occasion on which the two can be compared the agreement turns out to be exact. That may be fortuitous; but we may take advantage of the circumstance to use the combination of the figures for the wind in the stratosphere and the horizontal temperature gradient at thirteen kilometers to compute the latitude of the place of observation with an accuracy that may lead us to reconsider the common remark that meteorology is not an exact science.

The same equation applied to the troposphere, assuming normal values for temperature, gives correctly the rate of change of velocity with height, as shown in the corresponding diagram.

5.—The permanence of vortical motion about a vertical axis in the atmosphere, which is indicated by the long travel of cyclonic depressions.

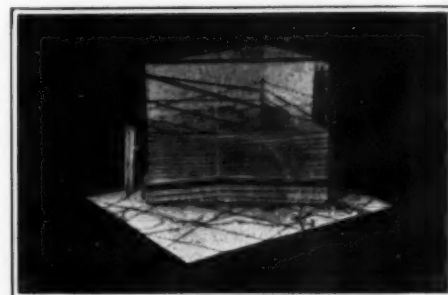


Fig. 3.—Model showing the distribution of temperature in the atmosphere on July 29, 1916. In each case the model stands on a map of the British Isles upon which the isobars are shown. In the interval of two days a layer of cold air spread itself along the base of the stratosphere from the east, and raised the surface pressure by about 10 ml.

From Equation C applied to the stratosphere it follows that a circulation in the base of the stratosphere with a given horizontal temperature gradient, such as is found there, will have only a limited extension upwards. With a wind velocity of 20 meters per second and a horizontal temperature gradient of 5 deg. per hundred kilometers, the extension will be 1.4 kilometers upwards; so that the vortex will be covered by a cap in which the velocity gradually falls off to zero within a very limited height.

For the extension downward the calculation is more complicated, but the computed change of velocity is very small, so that the vortex must be regarded as reaching the ground; and it would appear that a vortex extending throughout the troposphere terminating with a cap in the stratosphere is a possible reality.

Thus the hypothesis of an atmosphere in which the wind velocity is everywhere adjusted to balance the pressure distribution enables us to explain many of the ascertained facts that have been disclosed by the investigation of the upper air, and strongly supports the idea that the pressure distribution at the surface is controlled by the stratosphere and only modified locally by convection.

Against the control of the distribution of pressure by the upper atmosphere may be urged the formation of anticyclones over the relatively cold areas of sea and land, especially the winter anticyclones of the great continents of the northern hemisphere. For the local effect of surface cold we have to bring into account the effect of eddy motion, some examples of which are given in the "Meteorological Report of the Voyage of the 'Scotia' in 1912," by G. I. Taylor, published by the Board of Trade in 1913.

"The following references may be given for the statements enumerated here: (1) "Barometric Gradient and Wind Force." Report by Ernest Gold. M. O. Publication No. 190. (2) Shaw, Journal of the Scottish Met. Soc., vol. xvi, p. 167, 1913. (3) Shaw, Q. J. Roy. Met. Soc., vol. xl, p. 111, 1914. (4) "The Free Atmosphere of the British Isles." Report by W. H. Dines, F.R.S. M. O. Publication No. 202. C. J. P. Cave, "The Structure of the Atmosphere in Clear Weather." (Cambridge University Press.) E. Gold, "The International Kite and Balloon Ascents." Geophysical Memoirs No. 5. M. O. Publication 210e. The computations of Equations B and C are not yet published; the direction of the wind is regarded as not being subject to change with height. (5) Shaw, "Principles of Atmospheric Physics." Proc. R. S. E., vol. xxxiv, p. 77, 1914.

Fraud and Skin Eruptions*

Odd Cases of Self-Inflicted Injuries

By Sir John Collie, M. M. Aberd., Physician, County of London War Hospital, Epsom

Lesions of the skin may be produced in many ways; even simple rubbing with a wet finger, if persistently carried out, will raise an erythema. This, however, is a somewhat tedious method, and it is sometimes found that friction with the moistened end of a match or persistent pricking with a needle is resorted to, since these plans are quicker and more efficacious. Other methods are the application to the skin of a too hot water-bottle, of carbolic acid (frequently employed since it is very easily obtained), or of agents such as cantharides, mustard, "mustard leaf," or croton oil, all of which blister and may even produce superficial ulceration of the skin. More serious injuries, deep ulceration and gangrene, which are sometimes found, are generally produced by the application of strongly caustic acids or alkalis. One feature of these skin eruptions is that often a succession of diseased areas arise.

Dr. McKendrick, of Edinburgh, has kindly sent me a note of the following case.

A girl who had undoubted syphilis and a secondary eruption was about to be discharged from the Edinburgh Royal Infirmary when a fresh crop of eruptions suddenly appeared which was not characteristic of the disease. It subsequently transpired that some of the areas were produced by pinching the skin with the finger-nails, some by rubbing and scratching, and others by the application of heat. The hands were tied up and the whole rash disappeared.

Seven years later the same girl was brought to the surgical X-ray department of the same infirmary by the matron of a home for destitute girls, with a report that the girl had swallowed a large number of ordinary pins. X-ray examination was negative, and Dr. McKendrick, who, fortunately, remembered the girl's face, and said so, obtained from her the confession that she had not in fact swallowed any pins.

The case betokens a peculiarly twisted mental attitude and a moral obliquity which is interesting.

Nature of the Lesions.—These lesions appear suddenly and at irregular intervals; they may be single or multiple. There may be a simple erythema, bulle, or shallow ulcers; in rare cases severe, deeply-cut ulcers are found, or even patches of superficial gangrene. They have the following characteristics:

1. The condition produced is unlike any of the usual skin diseases.

2. According to the usual geography of factitious skin eruptions they occur in situations easily reached by the right hand of the patient, if she is right-handed, or on the opposite side if she is left-handed. Such situations, for example, as the front of the arm and the forearm, and the thigh and the leg are favorite sites. The area between the shoulder blades cannot easily be reached and this is generally found to escape.

3. They avoid the neighborhood of the mouth, nose, ear, scalp, knees, hands and the genital region. The soles of the feet are also avoided, as an eruption there would impede locomotion.

4. The lesions often have a characteristic aspect. Usually they run longitudinally, that is to say, in the length of the limb on which they are inflicted. The shape may be curious and suggestive. Ulcers, for example, may be perfectly circular, and in such cases have been produced, in the case of crude imitators, by the application of a coin soaked in some irritant; or, more rarely, they may take the shape of parallel scratches such as might be produced by a fork.

Eruptions following a straight line are unknown in dermatology. Any patch of dermatitis, therefore, which follows a straight line for any part of its margin is suggestive of fraud. A suppurating, angry dermatitis in a more or less straight line may be produced on the outer edge of the left forearm by the simple process of persistent friction by the right hand. It is well to remember that one is apt to be thrown off one's guard by a very inflamed angry-looking patch of inflammation; instinctively, from preconceived ideas and association, the appearance makes one think of disease. Many cases have been recorded where blistering has been produced by the simple process of cutting off a small piece of a mustard-plaster and applying it to the skin. The straight lines tell their own tale.

5. The surrounding skin is significantly healthy.

6. The alleged sensation of the part is usually abnormal; either the patient complains loudly of excessive pain, even when touched lightly, or else she professes to feel no pain when the part is freely handled.

7. The lesions sometimes have a way of appearing to order. If, for example, the examiner says in the hearing of the patient, "I should not be surprised if in the course of a few days we find an ulcer in such-and-such a place," the probabilities are that later an ulcer in due course appears there. Cases have been described where lesions starting at the periphery of a limb and subjected to the control of an occlusive dressing, such as a plaster-of-Paris case, have appeared higher and higher up the limb as the occlusive dressing has been extended.

8. Much assistance can often be gained by smelling the eruption. The characteristic smell of many acids can be recognized, and the case diagnosed at once. Litmus paper will often reveal an acidity which will at once arouse suspicion, for the normal exudation of a skin disease is alkaline.

In cases which are caused by hysteria other signs, such as stocking anesthesia, and so forth, can usually be elicited, and an important point to be remembered in all such cases is that they are usually associated with anesthesia of the palate.

Aids to Diagnosis.—The diagnosis will be assisted by a consideration of all of the above points. It should be remembered that occasionally where a strong caustic has been used a drop may run down the skin and leave a pear-shaped mark below the edge of the ulcer, which is lighter in color and shows a less intense inflammation than the primary lesion. The application of a proper occlusive dressing will often be found useful and will clear up any doubt that remains.

Dr. Edward Stainer, of the Skin Department of St. Thomas's Hospital, has kindly supplied me with a drawing the exact size of what he calls the "tell-tale trickle tail" which occurred in the left arm of a young housemaid, and was obviously produced by an acid. The central circular area was in a blistering condition with detached epithelium, surrounded with an irregular, erythematous border, the tail of a comma, as it were, representing the overflow of the acid.

Speaking generally, the flattened, sliding epithelium of a large blister in which there are no true pemphigus-like blebs, ought to make one suspect the possibility of artificial production.

Skin lesions, whether genuine or artificial, are often masked by a secondary dermatitis, which may be set up by scratching and the ingress of pyogenic organisms; these should be got rid of by the application of compresses and other suitable remedies. The character of the lesion depends not only upon the chemical employed to produce it, but upon the mode of its application; for instance, carbolic solution in certain strengths is an irritant, pure carbolic is an anæsthetic; an application of the former will, therefore, produce a dermatitis, the latter will whiten the tissues, and if the application is sufficiently strong will produce gangrene.

Many years ago, when I was in general practice, I was attending a patient for rheumatic fever. She complained bitterly of two painful spots in each buttock. Two small patches of whitened skin presented themselves, and I at once said, "These are burns with pure carbolic acid." The answer to the question whether a bed-pan was being used was in the affirmative. The trained nurse who was in attendance admitted, upon my putting it to her, that she was in the habit of disinfecting the bed-pan with carbolic solution. The fact that some pure carbolic had been unintentionally left on the utensil was perfectly obvious, but was denied. My patient, however, a woman of much intelligence, required no explanation. The nurse who had had her lesson, was forgiven, and there the matter ended.

It is often very difficult to discover the means adopted to produce the artificial lesions, for obviously the patient makes it his business to conceal in every possible way the fraud which he knows he has perpetrated. A curious case occurred recently in which a circumscribed area of the skin in the forearm presented a suppurating pustular eruption upon an indurated base. The patient was a nurse in a hospital. The case presented many unusual signs, but the true nature of it was soon re-

vealed (as it is in most cases when under hospital supervision) by the fact being disclosed that the nurse was a morphomaniac. She had inserted the hypodermic needle repeatedly within a small area, with the result described.

A somewhat rare but very interesting form of skin disease produced by artificial means is sometimes brought about by striking the skin vigorously with a hard brush, which produces a purpuric rash which has been called "hairbrush purpura."

There are physiological and psychological reasons which will suggest themselves to medical men why reasonable sane girls are found willfully to produce troublesome, irritating diseases; but here we are more concerned with the class of case in which pecuniary advantage is likely to be gained. Sequeira states that the payment of £5 to a servant employed in a large institution as compensation for dermatitis, alleged to be caused by irritant soap and alkalis, led to a crop of similar cases coming under his notice.

As a rule, an artificially produced skin lesion can be fairly easily diagnosed; but, as Dr. Norman Walker reminds us, it is one thing to diagnose a dermatitis artefacta and another thing to prove it. In his "Diseases of the Skin" Sequeira gives the following note about the case of a young girl where the lesions were obviously self-inflicted:

"The illustrative photograph shows the leg of a young girl in whom the lesions were remarkable for their arrangement in sets of three, all of the same length and equidistant. They consisted of rather deep longitudinal abrasions covered with dried blood and small crusts formed by dried exudation. Recent lesions and the stains of old abrasions are well shown in the photograph. The patient had complete anesthesia of the palate and right hemianesthesia affecting the face, limbs and trunk with the exception of a spot the size of a shilling over the right eyebrow, where sensation was normal. It was suggested that the excoriations were produced by a three-pronged fork, but scratching by the finger-nails might have caused them."

Dr. R. O. Adamson, of Glasgow, reports the following interesting case.

The patient was a young lady of more than usually attractive appearance in whom he detected nothing suggestive of the morbid tendencies which she exhibited. The illness began with "weeping eczema" of the chin, which was followed by a similar condition on cheeks, forehead, nose, neck, arms, and later the thighs and legs. The condition remained in spite of incessant treatment, and often appeared in places covered by dressings and bandages. Each patch was at first an acute erythematous flush which rapidly suppurated and healed by the usual crust. Their shapes were various, sometimes round, often square, and not infrequently linear. They healed rapidly, but the feature of the illness was the succession of diseased areas. The condition made the young lady a prisoner in the house for many months, and this was borne with remarkable patience. Dr. Adamson remarks: "I confess the idea of the complaint being factitious never occurred to me. Those who have met with such cases for the first time may understand my want of imagination. I was supported in my sympathy for my patient by a skin specialist who diagnosed dermatitis herpetiformis."

In due course the lady went to a well-known spa and was treated by two or three doctors with no benefit. Eventually the case was diagnosed by a well-known dermatologist as dermatitis artefacta. A nurse was sent in to watch the patient, but as after two months nothing was detected, fresh patches appearing, the friends of the patient were, with some difficulty, induced to send the lady to a nursing home where she was never left alone night or day, and was never allowed to leave the room for any purpose. On the fourth day a movement under the bedclothes led to the detection of the lady's hand holding most unsuspiciously a handkerchief in which was a small ragged piece of pumice-stone. When deprived of this her cure was rapid.

Two years later the lady complained of much gastric pain and vomiting of blood. There was plenty of blood, but it clearly had never been in the stomach, for it

*The Lancet.

lay as a pinkish layer at the bottom of a vessel of vomited milk. Notwithstanding her attitude was one of apparent *bona fides*, after a few days' careful watching she was informed that her illness was a feigned one, and so the matter ended.

A year later obstruction of the bowels was feigned, and constipation lasting a month was averred, the falsity of which was proved by another short sojourn in a nursing home.

Unfortunately, however, we often have to deal with the following much more difficult condition. Pre-existing skin disease is sometimes willfully aggravated and kept up by patients who derive a monetary benefit from continuing disability. It is an easy matter, for instance, for one whose hands have become inflamed as the result of using at his work too strong a soap or too strong a solution of soda to keep up the eruption by the occasional surreptitious application of the irritants which have in the first place produced it. How often does one see an old ulcer kept going when, if properly treated, it should have healed. The only way to deal with such cases is either to apply an occlusive dressing, when this is possible, or to arrange for the patient to be under proper medical supervision in an institution.

Trade Dermatitis.—In certain trade where irritants have to be habitually used dermatitis frequently occurs. The most familiar examples are the erythematous, raw-looking hands of those who habitually have to use strong alkaline solutions, for example, washerwomen, barmaids, etc. Hairdressers who use alkaline shampooing fluids sometimes suffer. Those who use aniline dyes, French polishers who use bichromate of potassium, grocers who have to handle sugar, carpenters working with teak and rosewood, tanners using arsenic, surgeons and nurses using disinfectants, painters using lead, masons working with silicate, photographers, and workers with chlorine, tar and paraffin are also liable to disease. Bakers are subject to a special form of eczema, the result of constantly mixing dough. This used to be called "baker's itch," which was probably a form of scabies, the result of the introduction of an acarid from an inferior sort of sugar with which flour used to be adulterated. A worker may have been engaged for years in a particular occupation without his skin suffering, but from some indefinite condition, such, for instance, as a lowered vitality, or it may be the accidental use of a stronger solution than usual, the skin resistance gives way, and a dermatitis is set up. Even when the condition has thoroughly healed there is sometimes a tendency to recur in the event of a continuous exposure.

The characteristics of the lesions produced are that they only appear in the portions of the body exposed to the action of the caustic, and are, therefore, almost entirely confined to the hands and forearms. This is not, however, an absolute rule, for if the worker is engaged with caustics in the form of a fine powder or a vapor, other parts of the body, more especially the axillae and groins, may be affected. It must be remembered that the clothing may become soaked in the irritant, and unexpected parts of the body may become affected. For instance, a case of acute eczema was recently found on both legs in a man whose occupation was that of cleaning down motor-cars; he used a crude form of paraffin, and his trousers had become soaked with it.

The various trades are responsible for an infinite variety of skin lesions. As a rule, they start with a simple erythema, followed by vesiculation, and eventually an eczematous condition is set up. When the process is chronic, we get the heaping-up of epithelium with formation of hard, horny skin, in which painful cracks are likely to occur. The backs of the hand, the tips and sides of the fingers, and the nails are usually first affected, the disease spreading up the arms as far as the irritant is able to obtain access. The difficulty of many of these cases is that they are so frequently masked by the secondary infection caused by scratching and the ingress of pyogenic organisms. In a suspicious case particular attention should be paid to the ends of the fingers and the finger-nails; and microscopic examination of the epithelium will often repay the searcher.

Dermatitis from Plants.—Many plants, either from the presence of irritating hairs or from their secreting an irritating oil, have the power of producing dermatitis in people who handle them. The most familiar example of this is the common stinging-nettle, but the primula family, especially *Primula obconica*, is particularly prone to do this, as also are *Rhus toxicodendron*, *Rhus venenata*, *Rhus diversiloba*, and *Laportea gigas*. Certain bulbs, also, such as the scilla produce an artificial dermatitis. *Primula obconica* is a poisonous plant which closely resembles the English primrose; its leaf contains a number of spines which readily attach them-

selves to the skin and set up an acute inflammation. Many people, however, seem to have an immunity from the poisonous effects. *Laportea gigas* (a tropical stinging-nettle) has a fruit like a raspberry, and the small hairs on the stems and leaves seem to have the power of setting up a dermatitis. The eruption produced by these plants, as a rule, starts on the lateral surfaces of the fingers and spreads to the back of the hand, involving the front and back of the wrist and front and back of the forearm. It closely resembles erysipelas, for which disease it is often mistaken. The eruption consists, as a rule, of an erythema covered with closely packed vesicles and a considerable amount of subcutaneous swelling. It generally lasts from a few days to two, three, or four weeks.

The Future of Oil for Marine Propulsion

UNDER the present circumstances any attempt to forecast the shipping outlook at the end of the war can only be made vaguely and in broad outline.

The two considerations which may be regarded as certain are that, first, the world will be faced with a shortage of tonnage, and, secondly, there will be a universal desire and urgent necessity to obtain the fullest efficiency from that which is available. Both these considerations point to a very widespread use of fuel oil in place of the use of coal for marine propulsion. When it is considered that the average efficiency of a coal-fired furnace is only in the neighborhood of 60 per cent, and that of an oil-fired furnace 80 per cent or more, it will be seen that such a superior thermal efficiency is an important factor. But this is not all. A ton of coal occupies forty-three cubic feet, whereas a ton of oil occupies only thirty-six cubic feet, and the latter can easily be carried in the double-bottomed ballast tanks. This saving in space, even if oil bunkers occupy the same positions as coal bunkers, would, in conjunction with the superior calorific value of the fuel and its higher thermal efficiency, combine to effect a saving of at least 45 per cent of the bunker space required, but when as above stated the double-bottomed tanks of the vessel are used for fuel oil storage, then the entire space, otherwise occupied by coal bunkers, is available for cargo carrying or other remunerative service.

The significance of this is that by structural alterations, which can in most cases be carried out without difficulty and comparatively small expense, the cargo capacity of the world's ocean transport could be increased by fully 5 per cent without adding a single ship, but simply by converting those existing to the use of liquid fuel.

A further important feature is the increased average speed of a vessel run on oil as compared with coal. An interesting comparison is furnished by figures of a prominent American steamship company which ran two vessels, one using coal and the other burning oil, on the same round trip. The oil burner showed a saving of twenty-five days in time on the round voyage, of which eighteen days were due to its increased speed and seven days due to the time saved in coaling ports. This increase of speed and saving of time can be safely estimated at not less than 10 per cent, which represents an equivalent addition to the carrying and earning capacity of the vessel during the year.

The large oil companies which specialize in fuel oil for marine purposes are confident that the end of the war will witness a very widespread adoption on the part of the leading shipping companies of this country and abroad of oil fuel. As above stated, the conversion from coal burning is a comparatively simple problem and it is said on good authority that some of our leading shipping companies have made arrangements for the conversion of their fleets to the use of oil immediately the war is ended.—*The Steamship (London).*

A Convenient Method of Fixing Carpets and Hangings

THE press button system with which we are familiar in gloves and garments has been applied by a European inventor for fixing carpets, tapestry hangings and the like. For instance, a small spring socket is inserted flush with the floor, and the carpet carries a corresponding projection, so that all that is needed to lay a carpet or rug is to push the buttons into the sockets. Again, the projections are mounted along a stout tape band and the sockets on another, quite like the usual pressure button. One tape is sewed to the rug and another can be tacked down upon an already laid carpet, so that the rug can be laid or removed instantly. Hangings can be put on the walls in the same way. Or in another case, the wall is covered with cloth fabric put on by the use of the present system, then the tapestry

hanging or panel can be mounted on top of this again, the whole being carried out by the use of the prepared tape. Curtains or portières can also be mounted; and all such material can be at once removed for cleaning. In case of fire, valuable hangings can be saved.

Exterminating Mosquitoes in Madagascar

A REPORT to the French Academy of Sciences tells of a unique experiment in combating a mosquito plague that proved surprisingly satisfactory. Myriads of mosquitoes infest the rice plantations of that country, and it occurred to Dr. Legendre to fight the marsh fever caused by the bite of the mosquito by introducing into the watercourses the "Cyprin" or red fish, which is a glutton as a devourer of mosquitoes, and still more so for the mosquito's eggs. The red fish is, moreover, exceedingly prolific. Dr. Legendre introduced 500 of these fishes into the streams of one district, and in five months they had multiplied to 10,000 and destroyed all the mosquitoes, freeing the whole region of rice fields from the malarial trouble. It appears, too, that the natives have found the red fish very much to their liking, and they are proving an important addition to their stock of food.

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